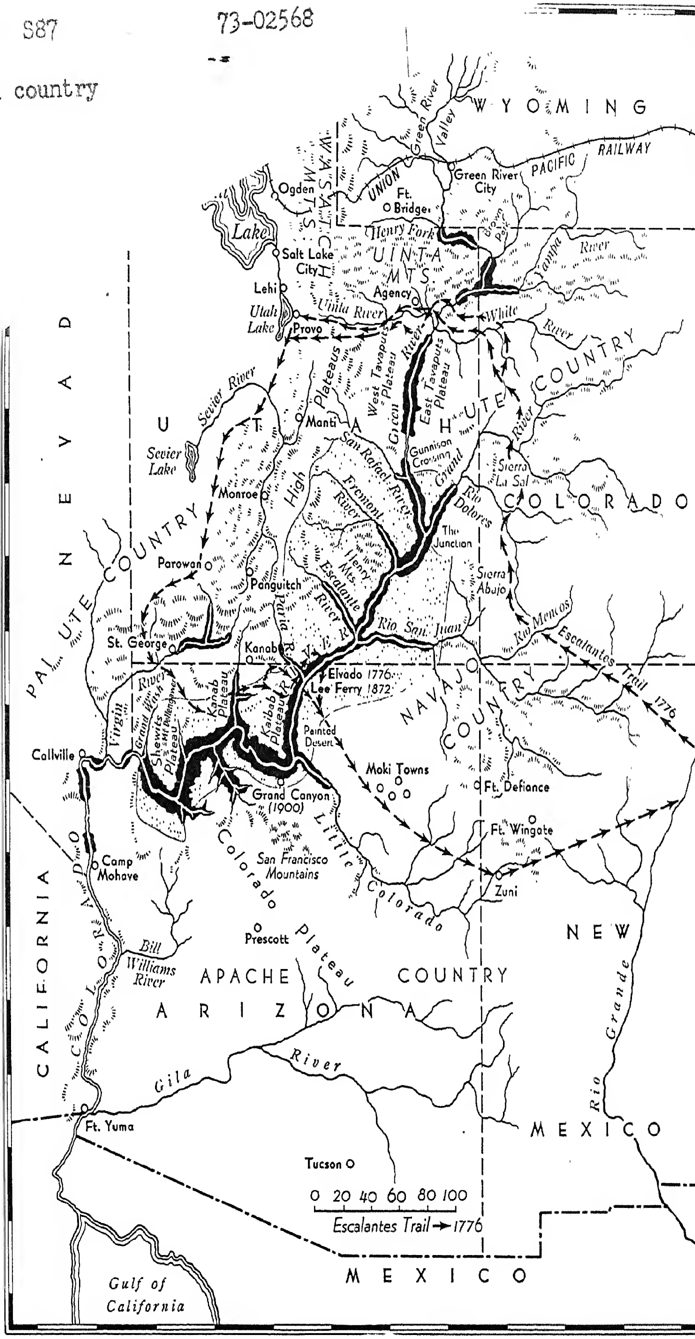
WYOMING
UNION PACIFIC RAILWAY
Green River Valley
Green River City
Ft. Bridger
Brown Park
Henry Fork
Ogden
Lake
Salt Lake City
WASATCH MTS
UINTA MTS
Agency
Yampa River
White River
Lehi
Utah Lake
Provo
Uinta River
Sevier River
Sevier Lake
West Tavaputs Plateau
East Tavaputs Plateau
Green River
UTAH
UTE COUNTRY
Manti
High Plateaus
San Rafael River
Gunnison Crossing
Grand River
Sierra La Sal
Rio Dolores
COLORADO
Monroe
Fremont River
The Junction
Henry Mts.
Parowan
Panguitch
Escalante River
Sierra Abajo
Rio Mancos
Escalantes Trail 1776
PAI UTE COUNTRY
NEVADA
St. George
Kanab
Rio San Juan
Paria R.
COLORADO RIVER
Elvado 1776
Lee Ferry 1872
NAVAJO COUNTRY
Virgin River
Grand Wash
Shewits Plateau
Kanab Plateau
Kaibab Plateau
Painted Desert
Callville
Moki Towns
Ft. Defiance
Grand Canyon (1900)
Little Colorado
Ft. Wingate
Camp Mohave
San Francisco Mountains
Colorado Plateau
Zuni
CALIFORNIA
Bill Williams River
Prescott
APACHE COUNTRY
NEW MEXICO
ARIZONA
Rio Grande
Gila River
Ft. Yuma
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Escalantes Trail 1776
Gulf of California

CANYO

The Romance of a Drop
And a Grain of Sand

BY

JULIUS F. STONE

Foreword by
HENRY FAIRFIELD OSBORN, President
The American Museum of Natural History
New York City

With more than 300 illustrations

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CANYON COUNTRY

THE ROMANCE OF A DROP OF WATER
AND A GRAIN OF SAND

First Edition

The Knickerbocker Press
New York

Made in the United States of America

To the Memory of

My Father and

My Mother

FOREWORD

The Grand Canyon country, delightfully described and illustrated in the present volume, covers 244,000 square miles of territory or one thirteenth of the area of the United States. It gathers in the waters of seven states, namely, Wyoming, Colorado, Utah, Nevada, New Mexico, Arizona, and California, states famous for their high plateaus and scenic grandeur. The geologic, scenic, and economic features of this region are on a scale so vast that they are almost beyond comprehension; even when one is in their midst they surpass a sense of reality.

Passing through the Green River Canyons, the north entrance to which the present writer visited in 1877 as a youthful explorer, one enters the northern portal to the plexus of canyons below, which culminates in the Grand Canyon of the Colorado, more than a mile in depth, bordered by side canyons many of which in themselves are among the greatest scenic wonders of the world. This central area with its maze of canyons is without doubt the most remote and inaccessible region within the domain of the United States, exclusive of Alaska. From the mouth of Green River to the Grand Wash, a distance of 500 miles, there are only three points at which it is possible to reach the Colorado River in a wheeled vehicle. In the 1215 miles from the mouth of Green River to the Gulf of California the bed of the Colorado River drops 4000 feet. The bounding rock walls are impressive not only for their height but for their varied colors. At the Bass Trail crossing, where the river bed is 2000 feet

above sea level, the geologic section towers 4900 feet above the bed of the river.

The upper tributaries of the Colorado River system rise in the high mountains of Wyoming, Colorado, and Utah, where precipitation, especially in the form of snow, is heavy. The measured annual discharge of water by the Colorado River system for the fifteen years 1909 to 1923 varied from 10,000,000 to 20,000,000 acre-feet with an average of 17,000,000 acre-feet. This large volume of water, the monthly discharge of which is greatest during the months of May and June, produces frequent floods which are a serious menace to the cities, towns and large irrigated areas in the delta region near Yuma and the Imperial Valley. The property values in the delta region exceed $100,000,000.

The canyon section of the Colorado River system offers one of the largest concentrations of water and hydro-electric power sites in the United States, it being exceeded in this respect by the St. Lawrence and the Columbia River basins, both of which are also international in extent. The basins of the Great Lakes equalize the flow of water at Niagara Falls and in the St. Lawrence River. A similar equalization of the flow of the Colorado River is possible by the development of reservoirs along its course from the mouth of Green River to Parker, Arizona, a distance of 950 miles. In the course of the last decade possible reservoir sites have been surveyed by the United States Geological Survey. The Hoover Dam in Black Canyon has already been authorized by the Federal Government and construction of it begun. While it is but one of a projected series its reservoir will tend to check the menacing floods, increase the amount of water available for irrigation and provide a new source of hydro-electric power.

Exercising thorough preparation as to equipment and great courage as to the conduct of the expedition, the author of the present volume, Mr. Julius F. Stone, and his small party set out on September 12, 1909, in rowboats from Green River City, Wyoming, to follow the course taken by Major J. W. Powell May 24, 1869, when with nine men and four boats he undertook to explore more than a thousand miles of the uncharted courses of the Green and Colorado rivers. The Powell party faced the unknown at every bend of the rivers, the trip was extremely hazardous, the little boats were frequently upset at the numerous rapids, and after three months of arduous work the party landed at the mouth of the Virgin River minus two boats and four men. In the immense depths of the rock-walled canyons Mr. Stone's party encountered the same hazards as the Powell party. Profiting by the experiences of their predecessors the Stone party traversed the canyon gorges of the Green and Colorado rivers and landed at Needles, California, on November 19, 1909, without the loss of a man.

Not being satisfied with telling about piloting small boats through the nineteen canyons of the Green and Colorado rivers, the author presents in Part I the romance of things geologic. Starting with the beginning of the Mesozoic era, about 200,000,000 years ago, there is discussed the mode of formation of the remarkable series of sediments exposed in the more northerly of the canyon walls. These rocks were deposited in a slowly sinking basin—a geosyncline. In the course of time the rocks of the geosyncline were deformed. Then followed the gradual uplift of the down-warped basin. As the land rose to greater and greater heights the Green and Colorado rivers continued to erode their beds to lower and lower levels. They are now actively engaged in their

middle and upper courses in attempting to lower their channels to approximate sea level. While they still have much work to do the great canyons which they have already cut in these parts constitute one of the great wonders of the world.

In Part II the author presents in short, crisp sentences the experiences of his party while in camp under strange surroundings, and as it floated down stream in rowboats or as the men piloted their way over rapids beset with pitfalls. Here we see mere human beings struggling with the powerful forces of nature. In the succeeding section are presented three hundred selected photographs of scenes in the canyons. The significance of these views and their correlation with the strata are revealed in the descriptions which appear on opposite pages. This unique series of illustrations reveals what running water with its stone tools has wrought in the canyon country of southwestern North America.

Geologists and physiographers the world over will welcome this substantial addition to our knowledge. While hundreds of Americans will envy the author his wonderful experience in passing through the greatest river canyons of the world, thousands of others will be grateful to him for this unparalleled photographic record with its accompanying observations and scientific comments.

Henry Fairfield Osborn

The American Museum of Natural History
New York City
December 15, 1931

CONTENTS

INTRODUCTION

This is only incidentally a narrative of personal experience. Primarily it is an attempt to set forth the charming story disclosed by the canyons of the Green and the Colorado rivers.

It is a story written in the sediments that were deposited beneath the waters of vanished oceans, lakes that have ceased to be, the deposits of river deltas, and the wind-blown sands of deserts that existed and disappeared long before the earth was habitable by man.

It covers the unknown millions of years that have elapsed from the Archean to the Quaternary periods, for these rivers have cut through and exposed the entire series of sedimentary rocks from the most recent to possibly the most ancient.

Some chapters may be fragmentary. An occasional page, even, may be missing; but as the trained paleontologist can from a few disarticulated fossil bones reconstruct in their entirety the skeletons of animals long since extinct, so may the geologist read the marvelous romance that is written in the rocks and supply at least some of the missing pages by interpolation.

If the complete significance of our environment, whatever it may be, is disclosed at first glance, then either there is very little to be revealed, or else the limitation lies in the observer. So it is that they who never look below or beyond the surface of things are shut out from the greatest enchantments Nature can bestow.

There is a far finer joy in knowing a thing is *true* than in saying it is *wonderful.*

The headlong glory of Niagara holds in almost speechless emotion many who see nothing interesting in a drop of rain. Yet the raindrop makes Niagara possible, for it is Nature's greatest sculptor and historian. In the form either of water or of ice it grapples hill top and mountain with ceaseless persistence, dragging them piecemeal into the ocean depths, there to reform the embryonic sedimentary rocks of ages yet to be. But back of the raindrop is the miracle of the tiny molecule of water vapor that climbs the ladder of the sunbeam into cloudland to make possible the raindrop; and behind the water vapor is the ocean. So the never-ending procession goes on and on, but in such orderly sequence that it leads the inquiring mind to question with a wonder ever new and a delight that never ends.

Nature is a voice and a vision unto each one of us who comes to her open-minded and in search of truth, unto all whose eyes welcome the light whithersoever it comes, as well as whatsoever it discloses. But she cannot reveal all the glad surprises held in store if our eyes are dazzled by the presence of imaginary gods that exist only for the purpose of dancing attendance on the childish credulity of our prayers, and which have the effect of making the universe so pleasantly incomprehensible to the timid.

There is given here no discussion of the cliff ruins, the pictographs, or other inscriptions found in the canyons, because they lend themselves to so many different interpretations leading almost inevitably to controversy that it has not been thought worth while. Reference to our experience on the rivers is confined to recording herewith in a somewhat abridged form the daily journal of the organizer of the expedition.

Those who are interested in the thrills of river ex-

periences, and they *are* interesting, can do no better than to read "A Canyon Voyage" (1908), by F. S. Dellenbaugh, or Ellsworth Kolb's "Through the Grand Canyon from Wyoming to Mexico" (1915). No one can add anything to the straightforward, delightful excellence of these narratives. Neither can anyone add much to the experiences of the authors and live to tell it. Nor are such experiences to be undervalued, because they afford those rare instances brimming with heart's desire when all that we are is focused into a few brief moments of glorious life. The writings of Lewis R. Freeman, a member of the surveying party under Col. Birdseye, and a quite recent volume by Clyde Eddy are also interesting additions to the literature of the canyon country.

It has been difficult to put aside the temptation to print all, or at least some, of the photographs in color. The chromatic splendors of the canyons, with their endless variegations, naturally make a strong appeal to one who has sensed the wide range of their masterful harmonies. However, this very versatility has compelled a negative decision, since the color effects, being to some extent atmospheric, are so evanescent and so illusive that any colored print could show only a momentary phase of the continuous transformations that recast the whole ensemble into new and splendid combinations.

If the intense colorings so often seen were reproduced as accurately as possible, those unfamiliar with the canyons would be pardonably incredulous, while others who know them would at once appreciate the inadequacy of the attempt. It would be as futile as trying to picture the iridescence of youth's vanished springtime by remembering the song of a single bird.

Not considering myself wholly competent to supplement the photographs with such valid discussion as

might awaken an added interest in as well as arouse a keener appreciation of the inspirational charm abiding in that arid but enchanted land, I sought and obtained the coöperation of Dr. Willis T. Lee (now unfortunately deceased) of the United States Geological Survey, to whom largely goes the credit of interpreting in terms the layman can understand the meaning that lies behind the pictured presentation, which is only of value as the outward evidence of that long series of cause and sequence of which it shows the present apparition. It should be understood that whatever errors may be found are mine and are not chargeable to Dr. Lee. Incidentally, permission to reproduce photographs other than my own was secured by Dr. Lee.

At times the text describing the photographs may seem repetitious, but this has been considered less objectionable than continual reference to preceding pages.

CANYON COUNTRY

PART I

A BORROWED CHAPTER ON EROSION

A BORROWED CHAPTER ON EROSION

"There are men who will make you books and turn them loose in the world with as much dispatch as they do a dish of fritters," Cervantes remarks in "Don Quixote." Regardless of its other shortcomings, the present volume can hardly be charged with unseemly haste in arriving in the world of books. It is the result of the author's abiding interest in geology and many years of intimate acquaintance with that wonderland, the Canyon country.

The purpose has been to set forth as interestingly and accurately as possible in word and picture the story that is written in the rocks through which the river has cut its way so that the understanding mind may read the history of the plateau region from the time when its earlier strata were laid down on the bottom of a great sea to the present day.

Humanly speaking, there is no "spot news" element to be considered when one writes of that vast spectacle born of erosion and known as the Grand Canyon of the Colorado. What might be written to-day concerning the general aspect of the canyon would be quite applicable a hundred years from now; and likewise what has been factually said in the past concerning the great walled river and its environment is just as valid now as it was the day it was written. Consequently, there has been no occasion for haste.

Government reports are not usually classed as litera-

ture, and for a very good reason. Still, as always, there are exceptions. Notable among them for our purpose is Captain Clarence E. Dutton's truly splendid volume entitled, "Tertiary History of the Grand Cañon District."

Few government bulletins so splendidly combine such thorough mastery of subject matter with such a felicitous literary style. Captain Dutton has set forth so clearly the story of deposition and erosion that to attempt to do again the very thing so admirably done by him would surely be carrying coals to Newcastle. Unfortunately, Captain Dutton's book has long been out of print, so that very few people may ever read it.

Truth is truth, and beauty is beauty wherever one may find them. And so certain pages of Captain Dutton's most memorable writing are herewith reproduced, without further explanation and quite without apology. Consider first his clear exposition of the conditions under which the sediments were laid down during the long ages from the Carboniferous to the Eocene, and then his comprehensive history of the tremendous work of erosion which has since brought that region to its present aspect.

* * *

Primarily, my intention has been to reconstruct only the Tertiary history of the Grand Cañon district. But as in human affairs the events of any limited period are linked with those which preceded them, so here the Tertiary history is rendered more intelligible by reviewing

[1] Canyon and cañon, of course, are identical, the latter being the Spanish spelling of the word.

whatever knowledge we may possess of the events which prepared the way for it. Prior to Tertiary time the records are very obscure, and the conclusions we may draw concerning such remote events are very few and of the most general nature, yet not without value.

Of the earlier Paleozoic conditions prevailing in the Plateau Province we know as yet but little. Already many perplexing problems have arisen which will require much study to solve, and their solutions promise to be extremely difficult. Within the boundaries of the province exposures of rocks older than the middle Carboniferous are very few and far between. Those which have received attention hitherto are confined to the Uinta Mountains and the lowest deeps of the Grand Cañon. Limiting our attention to the latter region, we find beneath that system of strata which we have thus far treated as Carboniferous a great variety of beds which range in age from the Archean to the Devonian. Throughout the Kaibab and Sheavwits divisions we find the so-called Carboniferous resting sometimes upon highly metamorphic schists of undoubted Archean age, sometimes upon the eroded edges of strata which have yielded Cambro-Silurian and Silurian fossils. In a single instance in Kanab Cañon Mr. Walcott found in a similar situation a very limited exposure of beds bearing fossils of Devonian age. In general, the rocks classed as Carboniferous rest upon the Archean, while the older Paleozoic beds come in only at intervals. The contact is always unconformable and usually in a high degree. The horizontal Carboniferous beds appear to have been laid down upon the surface of a country which had been enormously eroded and afterwards submerged. In the Grand Cañon this single fact is indicated to us throughout the length of a long, narrow, and tortuous cut thousands of feet in

depth. But if we pass westward or southward, beyond the limits of the great Carboniferous mass, we find a vast region where a similar state of facts is presented. The Sierra Country of central and western Arizona, of Nevada, and western Utah shows remnants of the Carboniferous resting with great unconformity upon older Paleozoic rocks and upon the Archean.

Probably there is no instance to be found in the world where an unconformity is revealed upon such a magnificent scale as that displayed at the head of the Grand Cañon, and certainly none amid such impressive surroundings. It is all the more suggestive because it is the type and symbol of a great fact which prevails over a region large enough for an empire. It assures us that in early Silurian time this region received enormous deposits of detritus which were faulted and flexed; that they were afterwards raised above the waters with the accompaniment of volcanic action; that they were ravaged by an erosion commensurate with the grander examples of that process which are proven to have occurred in much later stages of the world's history; and that the region was again submerged.

With the Carboniferous began that long era of deposition which extended without any real break into Tertiary time. The record of each period seems to be complete in the strata, and the deposition was apparently continuous over the area of the Plateau Province taken as a whole, though here and there we may detect evidence of a brief interruption in some small areas. There are some general facts connected with this process of accumulation of strata which merit special notice.

The strata of each and every age were remarkably uniform over very large areas, and were deposited very nearly horizontally. In the interior spaces of the province

we never find rapid increments or decrements of the strata. They do indeed vary in thickness, but they vary in the most gradual manner. Around the old shore lines, however, which form the present borders of the Plateau Country, we find the volumes of the strata much larger than elsewhere. But as we depart from them towards the heart of the province, we observe, in the course of two or three leagues, a considerable diminution in their thickness, and thenceforward the attenuation is so slow that we discover it only by comparing correlative sections many leagues apart. Very analogous is the constancy of lithological characters. As we trace the individual beds from place to place, we find their composition to be as persistent as their thickness. The sandstone of a given horizon is always and everywhere a sandstone, the limestone a limestone, the shale a shale. Even the minuter structure of the beds is similarly maintained, and features which are almost abnormal are equally constant. The Jurassic and Triassic sandstones are everywhere cross-bedded after their own marvelous fashion. The singular cherty limestones at the summit of the Carboniferous are quite alike in the brink of the Grand Cañon, at the junction of the Grand and Green rivers, and in the borders of the great Black Mesa at the south. The curious Shinarump conglomerate is the same in Pine Valley Mountains, in the terrace at Kanab, at the base of Echo Cliffs, and in the Land of Standing Rocks. The lower Triassic shales and upper Permian shales, with their gorgeous belts of richest colors and beautiful ripple marks, and with their silicified forests, have hardly varied a band or a tint from the brink of the Sheavwits to the pagoda-buttes of western Colorado. Still there are exceptions. The great Jurassic white sandstone fades out from the northwest to southeast, and we are in doubt, at

present, whether it failed of deposition or is blended with the Trias. Other members might be mentioned which undergo slow changes from place to place. But such changes are always very gradual. Nowhere have we found thus far what may be called local deposits, or such as are restricted to a narrow belt or contracted area.

All of these strata seem to have been deposited horizontally. Even the base of the Carboniferous has a contact with unconformable rocks beneath, which was but slightly roughened by hills and ridges. In the Kaibab division of the Grand Cañon, while the great body of Carboniferous strata was horizontal, we may observe near the brink of the inner gorge a few bosses of Silurian strata rising higher than the hard quartzitic sandstone which forms the base of the Carboniferous. These are Paleozoic hills, which were buried by the growing mass of sediment. But they are of insignificant mass, rarely exceeding two or three hundred feet in height, and do not appear to have ruffled the parallelism of the sandstones and limestones of the massive Red Wall group above them.

Another consideration is as follows: as we pass vertically from one formation to another in the geological series, we observe the same diversity of lithological characters as is found in other regions. The limestones occur chiefly in the lower Carboniferous, and in very great force. At the summit of the Carboniferous also are 700 to 800 feet of calcareous strata. But in the Mesozoic system limestones are rare, and constitute but a very small portion of the volume. By far the greater part of the entire stratigraphic column is sandstone, and the various members of this class show great diversity of texture and composition. Some are excessively hard adamantine quartzites, very many are common sand-

stones in massy beds. By small gradations these pass into sandy shales, containing more or less argillite, and such shales form a large proportion of the bulk of the Permian and Trias. These shales in turn pass into marly beds, which have vast thickness in the Cretaceous and form a considerable portion of the Eocene. Beds of gypsum are also frequent, forming thin separating layers in the shaly divisions, and sulphate of lime is a very important ingredient of the arenaceous strata from the base of the Carboniferous to the summit of the Jurassic. Besides its occurrence in distinct bands of nearly pure gypsum, it plays the part of a cement in the sand rock, and is also richly disseminated in the form of selenite in the sandy shales. On the other hand, there is a marked absence of such rocks as clay-slate. The slaty structure and composition has not hitherto been observed anywhere, so far as I know, and though argillaceous rocks are very voluminous in the Cretaceous they are charged with calcareous matter, and are very distinct from the ordinary clay-slates of the Appalachians.

Thus it will be noted that while the strata are remarkably homogeneous in their horizontal extensions, they are very heterogeneous in vertical range. And this heterogeneity is found not only in the chemical constituents, but also in the texture and in the mechanical properties of hardness, compactness, and solubility. This consideration is an important one, since upon it depends the result which is obtained by the attack of the eroding elements—the architecture of the cliffs and profiles.

Another general fact of importance is, that during the Mesozoic ages the surface of deposition was maintained very nearly at sea-level throughout the entire province. With regard to the Carboniferous strata it does not yet appear that the same was true. From such

meager knowledge as we possess, there may be some reason for the opinion that the Carboniferous sea had a considerably greater depth during the earlier and middle portions of that age than during the later portion. The lower Carboniferous strata (Red Wall group) consist chiefly of limestones, and the overlying lower Aubrey group corresponding to the coal measures is a series of sandstones of exceedingly fine texture and often gypsiferous. There is a notable absence in these beds of signs of very shallow water, such as ripple marks, cross-bedding, coarse clastic material, and littoral remains, organic or otherwise. The fauna, as usual, is an unsafe guide, and must be regarded as noncommital. On the other hand, there is no reason to suppose that the depth was at all profound. It is rather by contrasting the total absence of the signs of very shallow water with the presence of decisive signs of it in the Mesozoic and Permian, that we are drawn to the inference of somewhat greater marine depths in the early and middle Carboniferous.

In the upper Aubrey series we come upon some indications of shallow water, and from the base of the Permian upwards these are ever present. In the Permian, Trias, and Jura we find instances of those peculiar unconformities by erosion without any unconformity of dip in the beds. Perhaps the most widely spread occurrence of this kind is the contact of the summit of the Permian with the Shinarump conglomerate which forms the base of the Trias. Wherever this horizon is exposed this unconformity is generally manifest. Between the base of the Permian and the summit of the Carboniferous a similar relation has been observed in numerous localities, and there is a similar instance in the lower Trias. It has also been detected between the Trias and

Jura, and between the Jura and Cretaceous. We are tempted to ask here, whether such unconformities, without the slightest trace of permanent displacement in the strata, may not have been due to oscillations in the regional sea-level rather than to movements of the land?

One of the more striking features of the lower Trias is the occurrence of a vast abundance of silicified wood. It is not uncommon to find large tree trunks imbedded in these shales in good preservation. They are also found in a fragmental condition among the pebbles of the Shinarump conglomerate. These petrifactions are found over a wide extent of country from the Sheavwits Plateau along the front of the Vermilion Cliffs to the Paria, and again far to the northward at the base of Thousand Lake Mountain in the district of the High Plateaus.

These occurrences and others, which will soon be specified, point decisively to the inference that during the era of accumulation, lasting from the closing stages of the Carboniferous to the Eocene, the surface of deposition never varied far from sea-level, and now and then the waters retreated from it, but only for very brief periods. On the whole the deposition proceeded almost continuously. It necessarily follows that in the long run the underlying beds sank deeper and deeper as the newer ones were piled upon them. This fact is but a repetition of what is found in other regions where the deposition has been very heavy. The strata subsided as rapidly as they were formed. It was true of the Appalachians, of the Pacific coast, of western and central Europe, and I think the same is true of all the areas of great deposition throughout the West.

When we reach the Cretaceous age we find that a little more light may be thrown upon the physical condition of the province, though much less than might be

wished. So large are the areas where this series is the surface of the country, and so readily does the mind restore it to the places from which it has been denuded, that we feel almost as if we saw this great formation in its entirety. Wherever we turn in the Plateau Province the Cretaceous tells us the same story. All over its extent it is a lignitic and coal-bearing formation. We find coal or carbonaceous shales from the base of the series to the summit. Very abundant also are the remains of land plants in recognizable fossils, and these fossils occur not only in the carbonaceous layers but in the sand-rock and marls as mere casts or impressions of wood and leaves. Intercalating with these are many calcareous layers which yield marine mollusca in the lower and middle Cretaceous, and brackish water mollusca in the upper Cretaceous. In a word, the parallelism, so far as physical and organic conditions are concerned, between the Cretaceous of the Plateau Country and the Carboniferous coal measures of England, Pennsylvania, and Nova Scotia, seems perfect. What the Carboniferous age was to the Appalachian region, such was the Cretaceous age to the great mountain region of the West.

A careful scrutiny of the facts presented by the Cretaceous strata of the Plateau Country brings up before us some very curious and perplexing problems. No one would hesitate to say that during the accumulation of these strata the surface of deposition must have been very nearly at mean sea-level. Yet the Cretaceous system varies from 3,500 to 8,000 feet in thickness in different parts of the province. The continuous area which they covered south of the Uintas surely exceeds 100,000 square miles, in which not a single mountain chain, not a hill, not even a perceptible undulation of the strata is known to have then existed. It seems at first very diffi-

cult to understand how so vast a mass of strata could have accumulated in such shallow waters and over so wide an area. And the difficulty becomes considerably greater when we recall the fact that coal was also accumulated at different horizons throughout the entire province. If the sea were everywhere so shallow and if notable portions of its area were raised above the surface sufficiently to permit the growth of land vegetation, it would seem difficult to account for the transportation and diffusion of so large a mass of sedimentary materials over the entire expanse. Possibly some of the difficulties will be lightened by the following suggestions.

Although to the eye the strata show no marked inclinations excepting such as we know have been produced in later periods, still there may have been, and probably were, very feeble slopes too small to be detected by the eye, and these feeble slopes if continued for any great distance would carry the surface down hundreds of feet. A slope of one degree means a difference of level of a thousand feet in less than eleven miles. Hence there is no difficulty in imagining that while some tracts were exposed just above the water level, there were still larger ones where there may have been more than a hundred fathoms of water. But it should seem that shallow water, provided the shallowness be not very extreme, would tend to a wider and more uniform distribution of sediments than waters which run off into great depths. The currents having less depth of cross-section would move more rapidly and constantly, while currents moving outward into deeper water lose velocity and transporting power. So far, then, is the shallowness of the Plateau sea from being an obstacle to our comprehension of the state of facts which the region presents, that it may be the key to the mystery. One of the most striking facts to be ex-

plained is the persistency of lithological characters over large areas and the very slight and gradual variations in the masses of strata from place to place. If these sediments had been brought down by rivers to a shore from which the waters steadily and rather rapidly deepened seawards, we might have looked for enormous masses of littoral beds which rapidly thinned out as they receded from the shores; for the moving currents might be expected to lose themselves in the deepening water. But with shallow waters, whatsoever currents might be generated—whether from tides, from large rivers, from oceanic drift, or from prevailing winds—would persist as far as the depths remained shallow. Some such explanation as this, if it be tenable, would greatly assist us in explaining the wide diffusion of cross-bedding displayed in the Jura-Trias. It is generally accepted as an explanation for ripple marks that they are formed in shallow and moving water, and ripple marks are almost as abundant here as cross-bedding.

It would be extremely interesting to know what was the relative distribution of land and water over the western part of our continent in the closing periods of the Cretaceous. In a general way we know that the greater portion of the West was submerged. We also know that considerable land areas existed there. Sometimes we can point with confidence to a particular area and assert that it was land in Cretaceous time, but as a rule we are in doubt about the land areas. The largest piece of terra firma which is known was the Great Basin area, and even here we are unable to fix more than a small part of its shore line. We are reasonably confident that some and perhaps most of the great mountain platforms of the eastern ranges were above the waters with submerged valleys between them. We also know, and the fact is a

momentous one, that nearly the whole of the vast region of the West corresponded in its physical condition to what we have inferred for the Cretaceous age of the Plateau Country. But detailed knowledge of the geography of the land areas in that age is exceedingly meager. Perhaps, however, we may make some very general statements which are not without value.

We cannot as yet affirm confidently that the Cretaceous ocean stretched from the lower Mississippi to the Pacific Ocean; but the facts now known indicate that if the two oceans were separated in that age the separation was only by a very narrow land area. We can travel from the Mississippi to the Pacific, between the thirty-fourth and thirty-seventh parallels, without being at any time more than fifty miles distant from some known mass of Cretaceous beds. If some gaps in existing knowledge could be filled up, we might be able to close up the vacant spaces in the distribution of the Cretaceous, and say that strata of that age once stretched continuously between the termini just mentioned. Indeed the only gap of importance is in the extreme southern part of Nevada and southern California. Every indication we now have raises a presumption of this complete connection.

North and south of this locality, where it is supposed that an arm of the Cretaceous sea reached out to join the Pacific, there lay land areas of considerable extent. The northern was the old mainland of the Great Basin; the southern was the Arizona land. The northern area was much larger than the southern. It still remains possible that the two were one continuous area joined by an isthmus, or that the Arizona mass was a long Malacca-like peninsula projecting southeastward from the former.

At the close of the Cretaceous important vertical movements were inaugurated, which finally revolution-

ized the physical condition of the region. Around the borders of the Plateau Province some important flexures were generated at this epoch, and portions were uplifted sufficiently to undergo a large amount of denudation. Perhaps the most striking instance of this is the one extending from the eastern and southern flanks of the Aquarius southward to the Colorado. This area consists of Jura-Trias strata, from which the Cretaceous had been eroded before the deposition of the Tertiary. Beneath the lava-cap of the Aquarius the lower Eocene may be observed resting upon the Jurassic sandstone, and a little further westward it lies across the basset edges of the Cretaceous. Southeastward from the Aquarius and along the course of the Escalante River the same relation is inferred to have existed, but the great erosion has swept everything bare down to the Jura-Trias, and the evidence of the extension of the Eocene here is mainly direct. But the two monoclines are in full view, between which the Escalante platform was hoisted, and their age is unquestionably pre-Tertiary and post-Cretaceous. These relations are repeated in many other localities, and they indicate to us very decidedly that the Cretaceous closed amid important disturbances.

Still the deposition of strata was not yet ended. It went forward with seemingly undiminished rapidity, but under circumstances somewhat different from those hitherto prevailing. Soon after the advent of the Eocene the waters became fresh, and remained so until they disappeared altogether. This change was not limited to the Plateau Country, but appears to have been general over the greater part of the western mountain region. In truth, I know of no more impressive and surprising fact in western geology than the well-attested observation that most of that area has been covered by fresh-water

lakes, and that the passage from the marine to the terrestrial condition seems to have been through an intermediate lacustrine condition. The marvel is not in the fact that here and there we find the vestiges of a great lake, but that we find those vestiges everywhere. The whole region, with the exception of the mountain platforms and pre-existing mainlands, has passed through this lacustrine stage.

When we take account of the peculiar circumstances our surprise may diminish in some measure, and the facts thus described may seem natural enough. The uplifting of the western region was a movement which acted unequally over the continent. Some portions were raised more than others. It is also to be considered that some of the inequalities of the surface existed before this general uplifting began. The result of this inequality must necessarily have been the production of depressed basins and intervening watersheds. Whether these basins would be completely closed, so as to form great lakes, or whether they should have drainage freely to the ocean, would depend of course upon the relations of the new axes of displacement to the older topography. If the new displacements merely accent and increase the older features, we should hardly look for the formation of lake-basins. But if the new displacements are in any marked degree independent of the old ones, and if their axes lie transverse or oblique to the older axes, the formation of lake-basins in a newly emerging country is inevitable; and if the area affected be very extensive the chances are that the basins will be either very large or very numerous—in any event covering the greater part of the area. Without speculating as to the cause, it may be laid down as a general fact that the broader displacements of the West which began in early Tertiary time are quite independent

of the older topographies, and the production of lake-basins by the new emergence seems a necessary consequence.

It is apparent in any event that the Plateau Country formed one continuous lake south of the Uinta Mountains. The vertical movements which followed the close of Cretaceous time shut it off from access to the sea. If we are at liberty to go on as we have done and to draw broad inferences from the drainage channels concerning the mode of evolution, we can very quickly frame a theory of the distribution of those vertical movements. Thus we know that during Cretaceous time the Plateau area was wide open to the ocean towards the southeast, or towards the Gulf of Mexico. For the Cretaceous system stretches from the heart of the province clear across New Mexico and into Texas, with no other interruptions than some short mountain ranges (themselves largely composed of Cretaceous strata) and such gaps as have very plainly been produced by Tertiary erosion. Let us assume that at the beginning of the Eocene, or very soon thereafter, the western and northwestern part of New Mexico was uplifted slightly more than regions either east or west of it; the axis of elevation trending nearly north and south. The effect would have been to make an almost, if not completely, closed basin of the Plateau Country.

With this hypothesis we are able to frame a very simple and intelligible account of the manner in which the Plateau Province finally was isolated in Eocene time from the ocean. In truth, three-fourths or more of its boundary had been marked out long before, perhaps as far back as the beginning of the Trias; and in the following way. On the northwest lay the Mesozoic mainland, now forming the Great Basin area. In some form or other the Wasatch was then in existence as a mountain

range. So, also, the Uinta chain on the north of the province then existed, but probably did not project so far eastward as at present and left a gap in the boundary along the course of the Green River. On the north-eastern side of the basin some of the great Park ranges of the Colorado were standing, though the sea may have washed their bases. But to the southeast the area was wide open to the Cretaceous ocean. On the southwest and south lay the Arizona mainland. . . . Whether this mainland was continuous with the Great Basin mainland we do not know as yet, nor is it material just here. If, now, the first effort of the elevating force which has raised the continent had acted with more effect upon the eastern than the western side of the basin, the result would have been to make this basin a land-locked area like the Euxine. Its outlet would necessarily have been along the lower courses of the Colorado to the Gulf of California, or perhaps straight westward to the Pacific.

Having thus obtained a consistent view of the manner in which the great Eocene lake of the Plateau Province may have originated, it now remains to follow out such changes as are indicated in its subsequent history. It should seem that the passage from the brackish water to the fresh water condition was quite sudden, and as the same is true of widely extended areas outside of this region, we are apparently obliged to assume that the movement of which this was a result affected the entire western portion of the continent, and that it was one of elevation. A considerable number of large lakes being formed, the next process was the desiccation of these lakes and the evolution of river systems. So long as the region occupied a low altitude this process, we may infer, would be very protracted. Before a large lake can be drained its outlet must be cut down. But several causes

in the present instance would combine to render this action very slow and feeble. The elevation being small, the declivity and consequent corrasive power at the outlet must be correspondingly small. Moreover, the waters issuing from a large lake contain little or no sediment; and sediments—sand, grit, et cetera—are the tools with which rivers chiefly work in corrading their beds. Corrasion by clear water is an exceedingly slow process.

It is not surprising, therefore, to find that the lakes produced by the first action of the elevating forces persisted for a very long time. This persistence is a general feature of the Eocene lakes of the West. The Plateau lake seems to have been one of the largest and most enduring, for it did not wholly vanish until the close of the Eocene. The volume of sediment accumulated upon its bottom was very large, ranging from 1,200 to more than 5,000 feet in thickness, and these deposits represent Eocene time exclusively. Here we are confronted by the same paradoxes as those we encountered in viewing the Cretaceous condition of the region; a tract which is rising yet sinking; a basin which is shallow, which receives great thickness of deposits, and yet is never full.

At length we detect evidence of the gradual cessation of deposit and of the progressive upheaval of the country. . . . In the southern portion of the lake basin only the lower Eocene was deposited, while in the northern portion around the Uintas the whole Eocene formation is present. Whence we infer that the final desiccation of the lake began in its southern or southwestern portions, and that the lake shrank away very slowly towards the north, finally disappearing at the base of the Uintas at the close of Eocene time.

We must also infer that upon the floor of this basin, as it emerged, a drainage system was laid out. Such a

drainage system would necessarily conform to the slopes of the country then existing. Taking the supposition already made, that the uplift was somewhat greater upon the eastern than upon the western side of the province, the configuration of the principal drainage channels would be very much like that now existing. The trunk channel would flow southwestward and westward, while the tributaries would enter it on either hand very much as the larger and older tributaries now do. The affluents on the south side are the San Juan, and Little Colorado, and Cataract Creek, which seem to be due to just such an original surface. On the north side of the Colorado the arrangement of the tributaries also seems to conform to the assumption. On this side the later movements of the strata have been such that the prevailing courses of the streams are almost always against the dips. But when we restore these displacements and deduce from them as nearly as we may the original conformation of the country, the positions of the tributaries at once become natural and easy of explanation.

The argument here adopted concerning the origin of the drainage system affords little scope for discussion. Rivers originated somehow. It seems almost a truism to say that they originated with the land itself, and that their courses were, in the first instance, determined by the slopes of the newly emerged land surface. No doubt there are many causes which may have changed the courses of rivers, and in the subsequent changes of position the original arrangements may have been lost and left no intelligible trace. On the other hand, there are certain conditions under which we may look for the highest degree of stability in the positions of drainage channels, and when we find such conditions to have prevailed continuously the question of origin becomes at once im-

portant, for it indicates to us an initial configuration of the surface, which must be taken account of and never violated in all subsequent discussion. All inferences or speculations concerning later displacements and many other groups of facts must be kept in strict subordination to it.

The Plateau Country is one in which the conditions have been remarkably favorable to the stability of the larger drainage channels. On the other hand, it has been singularly unfavorable to the stability of smaller or local drainage channels. The Colorado and its larger tributaries—those tributaries which head in the highlands around the border of the province—exhibit everywhere incontestable evidence that they are flowing to-day just where they flowed in Eocene time. But the smaller tributaries are wanting altogether in some large tracts, and where they do exist they usually disclose the fact that they are of very recent origin and have been determined by surface conditions of recent establishment. In the remainder of this discussion these facts assume great importance.

With the final desiccation of the Grand Cañon district began the great erosion, which has never ceased to operate down to the present time. Concerning the details of that process we know but little, and we can only guess at its general character during the earlier stages. Erosion is here associated with a large amount of uplifting, and we may conjecture that as the uplifting went on the inequalities produced by erosion became greater and greater, the valleys grew deeper, and the intervening mesas stood in higher relief. This is merely an application of the general law that the higher the country the more deeply is it engraved by erosion and the greater are its sculptured reliefs. Much, however, must depend upon

climate. But the Eocene climate of the West, so far as it is indicated by the strata and organic remains of that age, was moist and subtropical, and presumably the climate of the Grand Cañon district was similar.

During the latter part of Eocene time the degrading forces no doubt made great progress in destroying and removing the Mesozoic deposits, which originally covered the region. We cannot, however, in this district find any epoch separating the later Eocene from the Miocene. To all intents and purposes they formed here a single age. From the time when the great erosion was begun until it reached a certain stage (to be spoken of speedily) not a single detail can be pointed to beyond the principal facts of elevation and erosion. We are, so to speak, passing a long interval of time in the dark. We must, therefore, stride at once from the middle Eocene to an epoch which may be provisionally fixed at the close of the Miocene. From this epoch looking backward the total change wrought upon the region up to that time breaks into view. But we know only the beginning and the end. The intermediate stages are discerned only by the imagination. Yet I am tempted here to view this period in a way which may be in some measure speculative, though not wholly so. Some deductions may be made from the established principles governing erosion which may fairly claim to be something more than mere speculation.

At the close of the Miocene, or thereabout, the greater part of the denudation of the Mesozoic should have been accomplished, and it is worth while to inquire in what manner this work may have been done. . . . The attack of erosion is directed chiefly against the edges of the strata and the cuts are made by the corrading streams. The whole region had, during the long interval of Eocene and Miocene time, undergone a great

amount of uplifting, and this progressive movement itself constitutes a condition highly favorable to corrasion; for the higher the country rises the greater become the declivities of the streams, and of those factors which determine a stream to corrade the most potent by far is declivity. While the country rises, therefore, the streams are making the reliefs greater—are creating larger surfaces of edgewise exposure and longer and steeper slopes. Thus, every advantage is given the agents of erosion.

The area thus exposed to rapid denudation was a very large one, and the corrasion of streams apparently went on over its entire expanse, without any very great local variations of amount, except perhaps near the borders of the watershed. While the normal method of decay is expressed in the recession of cliffs, we must not suppose that single and comparatively straight lines of cliffs stretched across the whole region and slowly wasted backwards. We should rather conceive of the platforms as being cut by a labyrinth of drainage channels, ramifying over their entire expanse, and as being attacked within and without, and all around—as a great conflagration spreads through every square, street, and alley of a city. A state of affairs quite similar to that suggested here seems to prevail at the present time in the interior spaces of the Plateau Province. The drainage basins of the Escalante River, of San Juan, and indeed of that entire part of the Colorado which reaches from the junction of the Grand and Green to the head of Marble Cañon, are wonderfully dissected by countless cañons, which I am confident were in existence at this very epoch, though they have since been greatly deepened and otherwise modified.

It may also be of interest to inquire whether it is probable that cañons, architectural cliffs, buttes, and

mesas existed in the Miocene, similar to those now occurring. The answer to this must be largely conjectural, but it seems to me that the probabilities are against such a topography. The present features of the region are no doubt favored greatly by an arid climate. Still we know that cañons and cliffs may be generated in moist climates. But under a moist climate, other circumstances and conditions must be of a very exceptional nature to produce such features, and even if produced, they are evanescent. An arid climate not only tends to produce, but also tends to maintain them. Under a moist climate the tendency is to reduce them to normal forms. Further than this it seems useless to speculate.

The first indications of specialized events are associated with the beginning of the present Grand Cañon.[1] About the time that the river began to cut into the Carboniferous strata, some important changes in the condition of the region took place, which have left their imprints upon the topography. The climate appears to have changed from moist to arid. We have noted particular instances where this change manifests itself in the drying up of lateral streams. These indicate that when the Colorado began to sink into the Carboniferous strata, some cause dried up the very fountains, and they ceased to flow. No explanation seems at all adequate except the advent of an arid climate. If, then, we could fix the period at which this change of climate occurred, we should have strong presumptive reasons for selecting the same period as the one in which the present Grand Cañon originated.

[1] I use the term "present Grand Cañon" to designate the state of the cañon at the present time in the Carboniferous, in contradistinction to the more ancient state of the valley . . . within the Mesozoic strata, which have been swept away from the vicinity of the river, and now appear only in the terraces, fifty miles or more to the northward.

We know that the Miocene climate of the West was moist and subtropical. This is indicated by the great extent of fresh-water lakes in some portions of the West, their abundant vegetable remains, and the exuberance of land life. But the remnants of Pliocene time are usually of a different character. In the Great Basin we have many proofs of the arid character of that age, and it is equally evident throughout the Plateau Country that the Pliocene climate was in the main very much like the present. We cannot, it is true, correlate with precision any definite boundary between Miocene and Pliocene; but, with no unreasonable latitude, I think we may still say that the Miocene climate of the Plateau was a moist climate, while the Pliocene was arid, and that the transition from one climate to the other occurred near the close of the former age or near the beginning of the latter.

At the epoch when the cutting of the present Grand Cañon began, no doubt the district at large presented a very different aspect from the modern one. While the greater part of the denudation of the Mesozoic had been accomplished, there were some important remnants still left which have been nearly or quite demolished in still more recent times. The basalts of the Uinkaret and Sheavwits have preserved some extensive Permian outliers, and even these must have shrunken greatly by the waste of erosion during the long period occupied in the excavation of the Grand Cañon. Although the basalts which cap Mounts Logan and Trumbull are certainly very ancient, and are older than the faults—or at least older than a great part of the faulting movements—there is no assurance that they are as old as the origin of the present cañon. Still I do not doubt that they go back nearly as far, and they are certainly much more ancient

than the inner gorge at the Toroweap. At the time of their outpour large masses of Permian strata overspread the region. These are not limited to the few remnants described on the Uinkaret, but we find the summit of the Permian similarly protected by basalt in many widely separated localities. Thus the Red Butte south of the Kaibab division of the cañon has a basaltic cap which seems to be about as ancient as that of Logan. In the San Francisco Mountains may be found remnants of the same formation protected by lavas, though our knowledge is not yet sufficient to give us any opinion as to how great an antiquity should be assigned to those eruptions. No doubt they are Tertiary, but whether Miocene or Pliocene is unknown. In the valley of the Little Colorado some Permian masses have been similarly protected by basalt and still reveal nearly or quite the entire series. The Sheavwits Plateau contains these remnants with basaltic coverings more abundantly and upon a larger scale than any other plateau. Thus there is a general accord of testimony that at the period of the older basaltic eruptions very large bodies of Permian strata lay upon the Carboniferous platform. In truth, it seems as if the summit of the Permian then constituted the surface of the country, just as the summit of the Carboniferous does now. The fact that the older basalts wherever found rest upon the same geological horizon, viz., the summit of the Permian, suggests to us the further inference that the region near the river was then flat and destitute of deep cañons and valleys, such as now exist there, and, therefore, destitute of great hills, buttes, or mesas. The meaning of this is a base-level of erosion. The rivers could not corrade, because they had reached for the time being their limiting depth in the strata. The work of erosion would then be confined to leveling the sculp-

tural inequalities without the power to produce new ones or to augment the relief of old ones. This, it is true, looks at first like drawing a very broad and rather remote inference from a very slender basis, and would not be justified at all if it were not in general harmony with a wide range of facts. Many facts take form and coherence around it which would otherwise seem mysterious. Let us illustrate.

The condition of base-level is one in which the rivers of a region cannot corrade. As a general rule it arises from the rivers having cut down so low that their transporting power is fully occupied, even to repletion. This, in turn, involves the correlative fact that no elevating force has acted upon the region for a long period of time.[1] For the most part base-levels are prevalent during a cessation of the uplifting force. The recurrence of upheaval terminates the condition of base-level. The declivities of the streams are increased, their energy augmented, and their corrasive power renewed. New features are then carved out of the topography, or older ones are embossed in higher relief. A period of upheaval, then, is one in which the sculptural features of the land are generated and increased; a period of quiescence or cessation of vertical movement is one in which these features are obliterated. Now, in trying to form some conception of the process by which the great denudation of the Mesozoic was accomplished, we may suppose that the uplifting of the region went on (1) either at a constant or a slightly varying rate, or (2) through alternating periods of activity and quiescence. The results would be widely contrasted in the two cases. The former would give us an exceedingly rough and hilly country at all

[1] Other causes might be suggested, but this no doubt is the predominant one.

periods of the erosion; the latter would give us just such a country as we see at present. The inequalities produced during a period of upheaval would be smoothed off during the period of repose. As a matter of fact we may be confident that the upheaval in its later stages has been of the paroxysmal character. Of this the proofs are abundant.

We may then conjecture the reason for the somewhat remarkable fact that the same stratum of geological horizon is almost everywhere the surface of the interior platform of the Grand Cañon district. Before the last upheaval we may conceive of the region occupying the situation of a base-level in which the inequalities which may have existed were obliterated. We shall see more of this base-level hereafter.

We find at this epoch the first indications of the existence of the great faults. It does not appear, however, that these faults all originated at exactly the same epoch, and it is certain that their respective amounts of displacement have increased very slowly and gradually with the lapse of time. Again, we cannot be sure that all parts of one and the same fault were begun at the same epoch. Indeed, the evidence is overwhelming that the development of these dislocations has been a very slow and gradual process, and all that can be said concerning their condition in the particular epoch of which we are treating (close of the Miocene) is that they first betray their existence at that time. Before this epoch we know nothing of them; and at the time in question they were of inconsiderable dimensions for the most part. Their formation seems to have been incidental to the uplifting of the platform which took place about the time the present Grand Cañon began to cut. But concerning the nature of this association it is useless to speculate. In all the range

of geological phenomena I know of none more perplexing than a great fault, and until we have some semblance of a working hypothesis which may serve or help to explain them, it is useless to speculate upon the causes of particular cases.

We may also note the coincidence of the earlier basaltic eruptions with this period of uplifting and faulting. It has been noted as a fact of very general application, that volcanism is active during periods of upheaval, and becomes quiescent during subsidence. The relations of the two classes of phenomena in the Grand Cañon district appear to conform to the general rule.

The amount of upheaval which took place at the epoch in question may also be roughly estimated. It varies from 2,000 to 3,000 feet. The uplifting forces then suspended operations for a time, and the drainage system sought a new base-level. During this paroxysm of upheaval the outer chasm of the Grand Cañon was cut; the river corrading down to the level of the esplanade in the Kanab and Uinkaret divisions, but below that horizon in the Kaibab. The corrasion was probably done as rapidly as the country rose, or very nearly so. At first we may presume that only a narrow gorge was cut—like the upper portion of the Marble Cañon. But the river found its base-level soon after the uplifting ceased, and the cañon slowly widened by the recession of the cliffs. In this stage of the development an arid climate reigned throughout the district. Its effect is apparent chiefly in two ways: 1st, the paucity of lateral tributaries and in the meagerness of small details in the land sculpture, and, 2d, in the sharpness and abruptness given to all the cliffs, valleys, and mesa profiles.

The only tributaries which remained during this period were the large and more powerful ones which had

their sources far away in the highlands, around the margin of the watershed. Within the inner platform of the district no streams took their rise. The large tributaries continued to sink their lateral gorges in unison with the corrasion of the main river, but no new chasms were generated. On the contrary, some of the lateral tributaries, which for a time valiantly sustained a doubtful struggle for existence, at last succumbed and dried up, leaving their troughs opening into the main gorge far up near the summit of the cañon wall.

The sharpness and abruptness of profiles which characterizes the plateau scenery is not of recent origin, but dates back no doubt to the beginning of the Pliocene. An arid climate is an important factor in producing this effect. In such a climate weathering proceeds slowly. If the conditions are such as to produce a high efficiency in the agencies which transport the debris, the rocks will be left comparatively naked; little soil and talus will be formed, and little will be left. The attack upon the edges of the horizontal strata will thus be facilitated and the profiles will be determined chiefly by undermining. Such profiles are invariably cliffs.

We come now to the final upheaval which has brought the region to its present condition. The Colorado River, after remaining without corrasion at the level of the esplanade of the cañon during the greater part of Pliocene time, at length resumed the operation of sinking its channel. A new paroxysm of upheavel set in; the faults increased their displacement; the volcanic vents reopened. This time the upheaval was greater than before, amounting probably to from 3,000 to 4,000 feet. The narrow, inner gorge at the Toroweap was swiftly cut, and it is in this respect a type of the lower deeps of the entire cañon. Everywhere the rapid corrasion of the deeper gorges is

revealed. The epoch at which this latest upheaval took place is no doubt a very recent one in the geological calendar. It began most probably near the close of the Pliocene. That it has now ceased is almost certain. No trace of present movement can be detected in any of the faults, and it is certain that no movement tending to increase them has taken place in those portions which have been scrutinized. In the Uinkaret some lava-flows cross the hurricane fault, and though they must be thousands of years old they are not dislocated. If any vertical movement is now in progress it is nowhere betrayed, and it is unaccompanied by any of those collateral movements of faulting, which are usually associated with upheaval. During the last stage of the evolution of the region you have to consider a very interesting episode. The glacial period here intervenes between the arid climate of the Pliocene and that of the present time. As has been already remarked, the glacial period here was not icy, but rainy, and very probably colder than the present. In some localities it began to excavate systems of local drainage channels and to carve out minuter details of topography. In truth the amount of this work which was done in that period was quite considerable. The most striking instance is to be found in the ravines of the Kaibab. The smaller drainage of the Paria Plateau is another instance. West of the Kaibab we fail to find such conspicuous traces of the glacial period. The explanation of their absence or feebleness may be the fact that those western plateaus have scarcely any slopes upon which such a drainage system could readily find foothold, while the slopes of Kaibab summit and of the Paria platform are very considerable. The glacial period appears to have been of too brief duration to achieve any

very great results in this district. It may have increased the corrasive power of the Colorado and tributaries by furnishing a larger water supply, and there is decided reason for thinking that some of the cañons in the terraces were rapidly corraded and deepened at this time. Most of these lateral cañons in the terraces are slowly filling up with alluvium at the present time, but very plainly they were much deeper at no remote epoch in the past. The lower talus in some of them is completely buried, and the alluvium mounts up on breasts of the perpendicular scarps. In some cases a smooth floor of alluvium extends from side to side of what was originally a cañon valley. The recurrence of a climate sufficiently moist to sustain a vigorous perennial stream would probably sweep out all this unconsolidated alluvium, and return the valley to its former condition of an ordinary cañon.

The excavation of the Grand Cañon and the sculpture of its walls and buttes are the results of two processes acting in concert—corrasion and weathering. In discussing these processes it is necessary to take into the account the peculiar conditions under which they have operated, and these are chiefly the climate and the elevation of the country.

In common parlance it is customary to say that the river has cut its cañon. This expression states but a small portion of the truth. The river has in reality cut only a narrow trench, of which the width is equal to the width of the water surface. It has also been the vehicle which has carried away to another part of the world the materials which have been cut away by both processes. Opening laterally into the main chasm are many amphitheaters excavated back into the main platform of the

country. At the bottom of each is a stream-bed, over which in some cases a perennial river flows, while in other cases the water runs only during the rains. Like the trunk river itself, these streams, whether permanent or spasmodic, have cut down their channels to depths varying somewhat among themselves, but generally a little less than the depth of the central chasm. These tributaries often fork, and the forks are quite homologous to the tributaries in the foregoing respects. They too have cut narrow gashes no wider than their water surfaces. Down the faces of the walls and down the steep slopes of the taluses run myriads of rain gullies. When the rain comes it gathers into rills, which cascade down the wall-clefts and rush headlong through the troughs in the talus. Carrying an abundance of sand and grit, the waters scour out these little channels in much the same way as their united streams and rills cut down their beds in the amphitheaters and in the main chasm itself. But the work of corrasion by running water is limited to the cutting of very narrow grooves in the rocks, the width of the cutting at any given time and place being equal to the width of the water surface of the stream. Corrasion alone, then, could never have made the Grand Cañon what it is. The amount of material removed by that process is but a very small fraction of the total excavation. Another process acting conjointly with the corrasion, and in an important sense dependent upon it, has effected by far the greater part of the destruction. This additional process is weathering. In order to comprehend the combined results of the two, it is necessary to study their action in detail.

Mr. G. K. Gilbert, in his excellent monograph on the Henry Mountains, has embodied a chapter on "Land Sculpture," which sets forth, in most logical and con-

densed form, the mechanical principles which enter into the problems of erosion. In his comprehensive analysis may be found a discussion of the conditions under which the sculpturing forces and processes achieve such abnormal results as we observe in the Plateau Country. The perusal of that chapter will give a delightful definiteness to the geologist's comprehension of the subject, and the reader, however learned he may be, will take great satisfaction in finding a subject so complex made so intelligible. The principles laid down by Mr. Gilbert will be adopted here and applied. I quote from his work the following:

> The mechanical wear of streams is performed by the aid of hard mineral fragments carried along by the current. The effective force is that of the current; the tools are mud, sand, and bowlders. The most important of them is sand; it is chiefly by the impact and friction of grains of sand that the rocky beds of streams are disintegrated.
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> Where a stream has all the load of a given degree of comminution which it is capable of carrying, the entire energy of the descending water and load is consumed in the translation of the water and load, and there is none applied to corrasion. If it has an excess of load its velocity is thereby diminished so as to lessen its competence, and a portion is dropped. If it has less than a full load, it is in condition to receive more, and it corrades its bottom. A fully loaded stream is on the verge between corrasion and deposition. . . . The work of transportation may thus monopolize a stream to the exclusion of corrasion, or the two works may be carried forward at the same time.
>
> The rapidity of the mechanical corrasion depends on the hardness, size, and number of transient fragments, on the hardness of the rock-bed, and on the velocity of the stream. . . . The element of velocity is of double importance, since it determines not only the speed, but to a great extent the size of the pestles which grind the rocks. The coëfficients upon which it in

turn depends, namely, declivity and quantity of water, have the same importance in corrasion that they have in transportation.

Let us suppose that a stream endowed with a constant volume of water is at some point continuously supplied with as great a load as it is capable of carrying. For so great a distance as its velocity remains the same it will neither corrade nor deposit, but will leave the declivity of its bed unchanged. But if in its progress it reaches a place where a less declivity of bed gives a diminished velocity its capacity for transportation will become less than the load, and part of the load will be deposited; or if in its progress it reaches a place where a greater declivity of bed gives an increased velocity, the capacity for transportation will become greater than the load, and there will be corrasion of the bed. In this way a stream which has a supply of debris equal to its capacity tends to build up the gentler slopes of its bed and cut away the steeper. It tends to establish a single uniform grade.

Let us now suppose that the stream, after having obliterated all the inequalities of the grade of its bed, loses nearly the whole of its load. Its velocity is at once accelerated, and vertical corrasion begins through its whole length. Since the stream has the same declivity, and consequently the same velocity at all points, its capacity for corrasion is everywhere the same. Its rate of corrasion, however, will depend on the character of its bed. Where the rock is hard, corrasion will be less rapid than where it is soft, and there will result inequalities of grade. But as soon as there is inequality of grade there is inequality of velocity and inequality of capacity for corrasion; and where hard rocks have produced declivities there the capacity for corrasion will be increased. The differentiation will proceed until the capacity for corrasion is everywhere proportioned to the resistance and no further; that is, until there is equilibrium of action.

In general, we may say that a stream tends to equalize its work in all parts of its course. Its power inheres in its fall, and each foot of fall has the same power. When its work is to cor-

rade, and the resistance is unequal, it concentrates its energy where the resistance is great by crowding many feet of descent into a small space, and diffuses it where the resistance is small, by using but a small fall in a long distance. When its work is to transport, the resistance is constant and the fall is evenly distributed by a uniform grade. When its work includes both transportation and corrasion, as in the usual case, its grades are somewhat unequal, and the inequality is the greatest when the load is the least.

The foregoing analysis is applicable to the Colorado. Among the large rivers of the world considered as trunk streams draining large areas its condition and operations are exceptional, though by no means wholly unique. Nearly all large rivers along their lower and middle courses and along considerable portions of the larger tributaries have reached or nearly approximated to that condition of equilibrium of action which Mr. Gilbert speaks of, in which the transporting power is nearly adjusted without excess to the load to be carried; and they have little or no tendency either to corrade or to deposit. But the Colorado is corrading rapidly, and has doubtless done so during a great part of its history. . . .

We have seen that the work of corrasion, pure and simple, is limited to the cutting of deep and narrow gashes in the strata and to the grinding up of the larger fragments brought into the channels. The widening of these cuts into the present configuration of the cañon and the sculpture of the walls are the work of the process which is termed weathering. By far the greater part of the material removed in the total process of the excavation has been broken up and comminuted by the action of atmospheric reagents, and their mode of operation is worthy of careful study.

The peculiar cliff forms of the Grand Cañon, and

indeed of the province at large, would hardly be possible in any other country, for no other country presents all of the conditions which are necessary for them. These conditions may be summarized as follows: (1) The great elevation of the region. (2) The horizontality of the strata. (3) A series of strata containing very massive beds, which differ greatly among themselves in respect to durability, but each member or subordinate group being quite homogeneous in all its horizontal extent; in a word, heterogeneity in vertical range and homogeneity in horizontal range. (4) An arid climate.

I. It is at once apparent that great elevation is essential to the production of high reliefs in the topography by the agency of erosion. Only in a high country can the streams corrade deeply, and it is by corrasion that the features of this region have been originated and blocked out. The elevation, however, is a condition whose immediate consequences are associated with corrasion, while it affects weathering only secondarily or remotely. The principal effect is the determination of the heights of the cliffs and the magnitudes of the topographical reliefs in general. All this seems so obvious that discussion is superfluous.

II. No less obvious is the effect of the horizontality of the strata. The long flat crestlines, the constant profiles maintained for scores of miles along the edges of each stratigraphic series, would not be possible otherwise. To appreciate this it is only necessary to glance at the effects which have been produced by the monoclines which at wide intervals interrupt the continuity and constancy of the cliffs. No wilder scene can be imagined than the pinnacles, towers, and domes which bristle upon the flank of a great flexure, like the Echo Cliff or Water Pocket folds.

III. The condition of horizontal homogeneity with vertical heterogeneity presents considerations some of which are as obvious as the foregoing, while others are extremely complex. It is clear that if the strata now forming the escarpment of the Vermilion Cliffs had varied rapidly from point to point in respect to the thickness of the individual members, or in respect to their lithological characters, the action of weathering would have varied accordingly. The profiles would undergo rapid changes of form along the front. In truth, there is a certain amount of variability of just this character in that escarpment. The Vermilion Cliffs in the valley of the Virgen differ notably in detail from what they are at Kanab and near the Paria. The enormous sandstone member dwindles in thickness from west to east, and other members less conspicuous gradually lose identity, and the resemblance of the two widely separated portions of the wall is only general. But the change along the front is very slow and is nowhere abrupt.

The vertical heterogeneity is the character which gives complexity to the profile. Where the beds are numerous and where they differ among themselves as to durability, the profile becomes very complicated, like a very elaborate series of horizontal moldings. The extreme of simplicity is found in the Jurassic sandstone, where the cliff consists of a single massive stratum 800 to 1,000 feet thick and homogeneous from top to bottom.

IV. The effects of an arid climate are by no means simple nor intelligible at a glance. They appear only upon analysis, and the analysis must take cognizance of a wide range of facts. I cannot do better here than to have recourse to the excellent analysis of Gilbert:

All the processes of erosion are affected directly by the rain-

fall and by its distribution through the year. All are accelerated by its increase and retarded by its diminution. When it is concentrated in one part of the year at the expense of the remainder, transportation and corrasion are accelerated and weathering retarded. Weathering is favored by abundance of moisture. Frost accomplishes most when the rocks are saturated; and solution when there is the freest circulation. But when the annual rainfall is concentrated into a limited season, a larger share of the water fails to penetrate and the gain from temporary flooding does not compensate for the checking of all solution by a long dry season.

Transportation is favored by increasing the water supply as greatly as by increasing declivity. When the volume of a stream increases it becomes at the same time more rapid, and its transporting capacity gains by the increment to velocity as well as by the increment to volume. Hence the increase in power of transportation is more than proportional to the increase of volume. It is due to this fact chiefly that the transportation of a stream which is subject to floods is greater than it would be if its total water supply were evenly distributed in time.

The indirect influence of rainfall and temperature by means of vegetation has different laws. Vegetation is intimately related to water supply. There is little or none where the annual precipitation is small, and it is profuse where the latter is great—especially when the temperature is at the same time high. In proportion as vegetation is profuse the solvent power of percolating water is increased, and on the other hand the ground is sheltered from the mechanical action of rains and rills. The removal of disintegrated rock is greatly impeded by the conservative power of roots and fallen leaves, and a soil is thus preserved. Transportation is retarded. Weathering by solution is accelerated up to a certain point, but in the end it suffers by the clogging of transportation. The work of frost is nearly stopped as soon as the depth of soil exceeds the limit of frost action. The force of raindrops is expended on foliage. Moreover, a deep soil acts as a distributing reservoir for the water of

rains and tends to equalize the flow of streams. Hence the general effect of vegetation is to retard erosion; and since the direct effect of great rainfall is the acceleration of erosion it results that its direct and indirect tendencies are in opposite directions.

In arid regions of which the declivities are sufficient to give thorough drainage, the absence of vegetation is accompanied by absence of soil. When a shower falls, nearly all the water runs off from the bare rock, and the little that is absorbed is rapidly reduced by evaporation. Solution becomes a slow process for lack of a continuous supply of water, and frost accomplishes its work only when it closely follows the infrequent rain. Thus weathering is retarded. Transportation has its work concentrated by the quick gathering of showers into floods so as to compensate, in part at least, for the smallness of the total rainfall from which they derive their power. ("Geology of the Henry Mountains": G. K. Gilbert.)

In this analysis of Mr. Gilbert I fully concur. It remains only to apply the principles he has developed. The effects which he deduces from an arid climate in a high country are a scanty soil, a diminished rate of weathering, and a great efficiency of transportation. We must further consider the effects of these varied conditions upon a country composed of horizontal strata which are vertically heterogeneous. The paucity of soil lays bare the edges of the rocks. The gentler slopes or taluses being found in the softer beds, these are more readily weathered than they would be if the soil were more abundant. But harder beds are not so easily dissolved, and can be broken down only by the undermining resulting from the waste of underlying softer beds. Hence the hard strata form vertical ledges, while the softer beds form taluses or steep slopes, partially protected by debris and soil. In a word, the effect of an arid climate upon such a region as the Plateau Country is to increase the

amount of bare rock, to sharpen the profiles and make them irregular, and to generate cliffs. To enforce this idea, let us imagine a moist climate returning to this region. The rate of weathering in the harder beds would be accelerated and the fragments and finer material would increase the amount of soil lying upon the sloped edges of the softer beds and the weathering of the latter would be retarded. Vegetation would start into life and conserve this soil by clogging transportation, and the profiles would gradually lose their abrupt angular character and become softened and rounded, like those of the Appalachians.

PART II

JOURNAL OF THE TRIP THROUGH THE CANYONS OF THE GREEN AND THE COLORADO

PREFATORY NOTE

Since making the trip through the canyons of the Green and the Colorado rivers in 1909, I have written a number of letters to individuals who have inquired about some particular phase of our experiences. These letters constitute the only written record —and of course a fragmentary one at best—of our journey.

The purpose of this volume being exposition rather than narration, there has been no great temptation to spin a long-drawn-out yarn of adventure in the "gloomy depths," braving the awful peril of "rapids with railway speed," et cetera.

Poetry, Wordsworth once remarked, is emotion recollected in tranquillity. Narration all too frequently is experience viewed through a magnifying glass. Whatever the shortcomings of the present incidental narrative, it is at least free from subsequent imaginings or lapses of memory. Instead there is herewith presented the day-by-day journal of one member of the expedition.

There have been a few omissions of details regarding weather, temperature, and so forth. But there has been relatively little change in the material as it was written at the time, except for some little smoothing of phrasing, to render more easily readable the necessarily fragmentary or "telegraphic" style in which some of the observations and comments were originally set down in pencil.

Friday, September 10, 1909.

Mr. Charles C. Sharp, R. A. Coggswell, and I reach Green River Station, Wyoming, at noon. After securing a room at the hotel and getting our dinner, we find on inquiring that our boats have not arrived. There are in the express office some boxes which we leave, however, until the boats shall have come. We start a tracer for them by wire and then begin unpacking the things brought with us as baggage.

Saturday, September 11, 1909.

The boats have arrived during the night along with everything else that was still to come by express.

Nathan T. Galloway and S. S. Dubendorff come in from Vernal, Utah. All set about unloading the boats, which are apparently in good condition, except that the canvas decking over the front and rear cockpits is not waterproof, as it should have been, and the method provided for fastening it down is not as arranged for. The iron standards at each corner of the cockpit which should have been provided to hold the canvas sides and ends have been omitted entirely. Neither are the small bow and stern compartments provided with airtight covers according to contract. But we will try to get along.

Arrangements are made with a Mr. Morris to use his barn and corral for the purpose of unpacking and distributing the load each boat is to take. Galloway goes to a blacksmith shop and makes four iron handles, one of which is to be bolted to the stern of each boat, so they can be the more readily handled.

The weather is raw and blustering in the morning, with rain and sleet in the afternoon, a not very pleasing prospect,

but we shall doubtless have plenty of unpleasant weather to contend with before we reach Needles. At the telegraph office we are told there is a heavy snowfall at Rawlins, just east of Green River, so that trains cannot get through until the track is cleared.

Dubendorff and Coggswell both being light, it is arranged they shall go together in one boat. Galloway, Sharp, and I each having a separate boat, the provisions, camp equipment, and photographic supplies are apportioned to our three boats.

Sunday, September 12, 1909.

Galloway bolts the iron handles on the boats. Arrangements are then made to have the boats and the supplies hauled to the river just above the wagon bridge. This is done by 1:30, and as there is talk of a good many people coming between three and four o'clock, we pack everything into the boats as quickly as possible and start at 2:40 P.M. When I started for the river Mr. Morris said he would walk along and asked if among our supplies I had any whiskey. I replied, no. He then asked whether I had any moral objections to liquor. Again I answered no, but that on all previous trips into the mountains or elsewhere I had never taken any along, because I wished everyone, including myself, to be at his best both physically as well as mentally at all times. He then said that one of us might have an accident, and might need a temporary stimulant badly, and that if I did not object he would like to present me with a quart. Thereupon he stopped at a drug store, which he unlocked (it being Sunday), and gave me a bottle of rye whiskey, which was added to our supplies. (While it is a matter of no importance, still there is a certain gratification in stating that this bottle, unopened, survived the trip through the Canyons, and is still in my possession. Just when the contents will be consecrated to all Colorado River voyagers cannot now be stated, but probably not until some particularly auspicious occasion.)

Possibly eight or ten are on the river bank as we depart,

all wishing us good luck, but doubtful of our succeeding, and giving us a last warning not to go. Dubendorff is hung up on a sand bar for a while this afternoon. A few miles down stream we go into camp, at 5:10 P.M. on the left bank, among willows and cottonwoods. Galloway sets traps for beaver.

Monday, September 13, 1909.

Galloway caught one beaver, a fairly large one.

Here we repack our loads and consequently don't get started until 10:15 A.M., at which time there is a moderate wind from the northwest. Soon after starting Dubendorff gets hung up on a gravel bar for about thirty minutes, and as the boats don't handle just right, we make camp at 2:45 P.M. for the purpose of doing such readjusting as is found to be necessary.

Tuesday, September 14, 1909.

A few films were developed last night. Some are fairly good, others underexposed, but these should serve as guides in the future.

Start at 8:30. Weather beautiful. Pass Rush Creek at 10 o'clock. We reach Black's Fork at 11:30, where we shoot two widgeon. Stop for lunch at 12:15 on a flood plain on the east side. Off at 1:45 and soon come in sight of the Uinta range of mountains. We make camp at 4:30 opposite Bridger Bottoms in a clump of willows. I help Galloway calk his boat while Sharp and Dubendorff cook supper.

Wednesday, September 15, 1909.

Off at 9 o'clock. Galloway caught two beaver, but having forgotten to take up one trap, he has to go back for it after we have gone a mile or two. The red variegated stone which caps the buttes at Green River has dipped below water level, then has come up for a short distance, and is now below again.

Yesterday we passed several low vertical walls on the west side, composed of horizontal laminations, varying in color,

giving the effect of a long band of ribbon-grass, just above the water.

At 10:05 Sharp and Dubendorff both stick on a sand bar. Sharp gets off without wading, but Dubendorff has to get out in order to lighten his boat sufficiently to float it into deeper water.

We stop for lunch on the west side among some willows at 12:30. Opposite the flood plain where we are, the cliffs are light gray in color and of only moderate height. Sharp is not feeling well because of a headache. Off at 1:40 and at 4:20 reach the mouth of Henry's Fork, just south of the boundary between Wyoming and Utah.

As we are approaching this camping place we see some wolves or coyotes jumping up and down in the shallow water, either playing or fishing, but evidently very busy. We do not get close enough for a shot.

So far we have had a number of coyotes around camp each night but they are very shy and not in evidence excepting by the noise they make.

Dubendorff and I walk to the Larsen Ranch some miles up the creek, reaching there at dark and staying over night.

Thursday, September 16, 1909.

This morning a young lady, Mr. Larsen's daughter, hitches up a team of horses and brings us and our supplies to the river, but declines to take any pay for the assistance given. Everything is ready to start as soon as the fresh grub is packed on board. This work is done quickly, and we are off at 9:45 and enter Flaming Gorge at once. We see a beaver in the water. Galloway shoots it and it sinks. Before starting this morning I gave Coggswell all the maps, as well as Powell's and Dellenbaugh's books to check up, as he does no rowing.

We pass through Flaming Gorge, Horseshoe and Kingfisher Canyons. We stop for lunch at the mouth of Sheep Creek at 2 P.M., and as the boats, or rather their contents, need repacking, we camp here over night.

Here the course of the river is southwest, but it turns sharply

to the left about half a mile below the mouth of Sheep Creek. The walls are of gray sandstone. There is a reef or fold sloping to the southeast which ends where the river bends toward the left, at which point there is a fold sloping to the northwest. Between the ends of these the river flows.

The rapid in Horseshoe Canyon to which Powell refers rather conspicuously amounts to little or nothing at this stage of water. It may have been different in 1869.

Dubendorff goes fishing up Sheep Creek and catches one trout, a very fine one.

Friday, September 17, 1909.

Up at 5:10 in order to go with Galloway and take up traps. He shoots a coyote in a cave. Back to camp at 6:15. No beaver.

Off at 8:10, taking up those traps below camp and finding one beaver. Then we stop at an island opposite Hideout Flat, where Galloway scares out two deer. One passes quite near to Mr. Sharp, who shoots at it a couple of times as it swims across the river but does not get it. Attempting a third shot, he finds his rifle is empty, I having used it and neglected to refill the magazine. Sharp's failure to state his feelings on the subject with due asperity affords a fine example of self-control. I shall try to profit by it. Shortly after this we run the rapid above Carter Creek. It is rather long but not at all difficult. Still, a little water splashes into my boat. We reach Carter Creek at 10 A.M. and stop to remove the skegs from our boats. While I am doing this, Sharp, Dubendorff, and Galloway go up the creek and catch enough trout for lunch.

Leave Carter Creek at 1:50 and run all the rapids without difficulty except that I am hung up on a rock for about ten minutes, but have no difficulty in getting off. We land below this rapid, empty the water out of my boat, then go about three miles and make camp at 4:10 in a beautiful spot among large pines on the left side of the river. The walls here are probably eight hundred feet or more high and less abrupt than those we passed this forenoon. They have few vertical faces. The

river is generally a succession of moderate rapids, affording good practice for the heavier ones in Lodore and Cataract Canyons.

Saturday, September 18, 1909.

Start at 8:20 and at 9:30 reach "Ashley Falls," which Galloway inspects and decides to run by going through the second chute from the right bank (looking down stream). He takes his own boat through, then Dubendorff's. And when he starts with Mr. Sharp's boat, I follow in mine, but about fifty feet above the first chute, I have the bad luck to pull out the socket of my left oarlock. Still, the current carries the boat about where it should go, save that it brings the two boats uncomfortably close together. But Galloway gets out of the way quickly and avoids all danger of a mix-up. As soon as the boat slips between the first two rocks, a strong pull on the right oar enables me to miss the rock on that side, while the force of the current keeps me clear of the large rock in the middle of the stream. And so the boat goes through all right. I land below the rapid in an eddy, repair the oarlock by putting in a new socket, and we are off again at 11 A.M.

It is stated in a book of some authority that "the supplication of a righteous man availeth much." But as Galloway, who was immediately ahead of me, says he is certain I did not *pray,* my getting off so easily must be ascribed to some other kindly, though not less potent, influence.

While at the "Falls" we all looked carefully for the inscription which both Powell and Dellenbaugh report having found on one of the large rocks, but fail to find any trace of it. It has probably been obliterated by the weather in the interim. This is not a "fall" (vertical) at all, but a rather sharply accentuated little rapid caused by a number of large rocks having fallen into the river from the cliff on the right side, obstructing the channel to such an extent that there is a drop of probably five feet in fifty. The rocks, not the declivity, constitute the only element of danger.

Galloway says he and I are the only ones known to have run this rapid (though he ran it on a previous trip). At noon we land below a reverse curve in the river, at the mouth of Cart Creek. Off at 2 o'clock and run past "Little Brown's Hole" down to a small flat on the left, where we camp at 5. Galloway suggests this should be called "Two Cottonwood Park" because of two very large trees, though there are other smaller ones here. We pass two lively rapids and many ordinary ones below Ashley Falls, but have no difficulty in running them.

Sunday, September 19, 1909.

Here the country is much more open, the banks generally low, and the hills sloping gradually away from the stream on each side save in a few places where the walls rise from the water's edge. The country is covered with scrub cedar down to the flood plains, on which grow willows and cottonwoods.

We leave camp here at 9 o'clock and reach the mouth of Red Creek at 10:05. After inspecting the rapid, Galloway and I run through. Then Mr. Sharp and Dubendorff come through without difficulty. At 12 o'clock we reach Jarvie's ranch. No one is here, Jarvie having been murdered about a month ago. The ranch house is in great disorder, but we disturb nothing and go on. At 12:40 we stop for lunch on the right side on what would be an island at a higher stage of water.

Off at 2:20 and pass a cabin on the left bank, finding no one there. We reach Old Bridgeport P. O., Utah, at 3:30, then pass through a short canyon about one third of a mile in length, from which we emerge into a little park and then through Swallow Canyon, three or four miles long. About a mile below is a cottonwood grove on the left side, and here we camp at 6 P.M. among the willows and cottonwoods of a high flood plain. The mosquitoes are *very* bad.

The government reconnoissance map shows Beaver Creek as coming in above Jarvie's ranch in Brown's Hole (in Utah), whereas in fact it joins the Green about ten miles lower down and a mile or so east of the Colorado line in Colorado.

Monday, September 20, 1909.

We start at 8:15 A.M. but Galloway has to go back after his dog while the rest of us drift on with the current. At 8:35 we pass the mouth of Beaver Creek. We see many beaver signs, but as it was late when we made camp last night, Galloway did not set any traps. The country continues about the same as that through which we passed yesterday. The main hills are ten miles or so apart on each side of the river, while near the stream we see strata of sandstone, clay, and imperfect conglomerate, all apparently in place. Overlying these are heavy gravel beds.

Below Beaver Creek we pass into a low canyon having walls about forty or fifty feet high and rising quite abruptly from the water, especially on the west side, but it is only a quarter of a mile or so in length and then opens out again. In this little canyon, as well as in the two preceding ones through which we passed yesterday, there are many empty swallow nests. The walls, of blackish red sandstone and practically undisturbed, show many cleavage planes due to lateral pressure. We pass several ranch buildings near the river. From one of them a couple of women salute us by waving a white cloth as we go by. There is a very heavy wind which at times amounts almost to a gale, so that it requires the hardest kind of work to make any headway against it. At 11 A.M. to-day we come into sight of the upper portal of Lodore Canyon.

At 12:30 we land on the left side of the stream on a flood plain overgrown with cottonwoods and a great bed of wild roses. Off at 2 P.M., and at 2:50 we stop at Pruitt's ranch just above the mouth of Vermilion Creek and I have the delightful privilege of holding and playing with a little baby boy two years old. We drop around to the end of the point where the river turns southwest, and as the wind is very high, we go into camp at 3:20. The country is still very open, sloping gently back from the stream excepting toward the southwest, where the river cuts very quickly into the foothills of the main Uinta Range.

Our camp is among thick willows, with a large grove of cottonwoods a hundred feet away affording good shelter from the wind and a possible storm, though there is little likelihood of any.

Below the mouth of Beaver Creek on the left bank is a small lake, residue from the last high water. Here we find numbers of wild ducks and geese, probably one or two thousand, evidently on their southward migratory flight. Then a short distance below on a sand bar in the river we again find hundreds of them, but purposely drift by without disturbing them, except to cause a lot of honking by the geese and quacking by the ducks. We might kill many by shooting into the mass, but there is no reason to do so.

Tuesday, September 21, 1909.

We start at 8:30 and at 9:25 stop at the camp of the U. S. R. S. engineers, just at the head of Lodore Canyon. We find no one but a young woman, Miss Ethel Chew, who is cooking for them. She tells us to help ourselves to the use of any of their tools which we may have occasion to use. But we mostly need and take empty tin cans to be used in patching our boats, should that become necessary. At 10 A.M. we enter Lodore Canyon.

About two miles below Dubendorff calls out that there is a beaver in the water. This is just as Sharp and I have landed above the head of the first rapid. A moment later it rises about thirty feet away and Sharp shoots it and then catches it as it floats near a lot of drift which projects into the stream. After running the first rapid we go on about two miles farther where we find the reclamation engineers (Mr. Jones, Superintendent) at work, testing the river bed for a dam foundation. We stop to greet them and go on.

Galloway runs the first real rapid, then comes back and takes Sharp's boat. I follow, and Dubendorff comes last. At 2:10 we stop for lunch under a box-elder tree in a beautiful, quiet spot where the cliffs are probably one thousand or more feet high on each side and nearly vertical. The wind has abated.

After we fix our oars by covering the ends of the blades with tin we will try to reach Disaster Falls, so named by Powell, to-night. The whole strata dip gently to the south. Galloway says the water is higher than at any previous time when he has been through, save one, and the rapids correspondingly accentuated.

We are under way again at 3:15 and run several rapids until 4:45 when the wind having risen and become gusty again, we camp among the cedars on the right bank, where the river runs in a southwesterly direction and opposite the highest walls we have as yet seen.

This is by far the most picturesque camping place we have found. The moon, in the first quarter, blinks through the cloudy sky above us. The whole environment is charming. Galloway caught two beaver last night.

Wednesday, September 22, 1909.

At 8:20 we start and at 8:45 reach the head of Upper Disaster Falls. We portage half the loads to the foot of the first rapid. Then Galloway decides to run his boat through and if successful to bring the rest down. While this is being done, Sharp and I level it up, finding the descent to be twenty-one and five-tenths feet in a distance of 1968 feet. Galloway then takes the boats to the foot of the middle rapid. We make coffee while he examines the third rapid, churning up against the foot of the cliff on the right side. We find fresh tracks of four mountain sheep (bighorn), but do not catch sight of any. The cliff on the west side of the river just below the second rapid is 1568 feet high, and the one on the east side, a little lower down, facing the foot of the third rapid, is 1482, by triangulation. The fall of the third rapid is fourteen feet in twelve hundred. Lunch being finished at 1:40, we portage part of the loads around the third rapid while Galloway runs all the boats through without serious difficulty. Then we load up and are off at 3:30, with no mishap whatever. This is the rapid where one of Powell's boats was wrecked and lost.

The illustration shown of Disaster Falls, opposite page twenty-seven of Powell's "Colorado River of the West," is inexcusably inaccurate. This is not a "fall" in any sense whatever, and should not be so named.

We go on about a mile and at 5 P.M. camp below the foot of an island on the right bank among cedars, willows, box-elders and lots of poison ivy.

Our camp is at the mouth of Pot Creek, which comes in from the west. A little above here a dike of dark rock showing evidence of great heat cuts across the canyon. Being more easily weathered than the adjacent rock, it has left a small gulch on either side of the stream.

The sky is beautifully opalescent in the north since sunset. The cliff on the east side glows in rich vermilion under the reflected light of the sky.

Thursday, September 23, 1909.

Everyone sleeps a little late this morning, being somewhat worn out with yesterday's efforts. Off at 8:45 and at 9:30 we come to a lively rapid above Dunn's Cliff. On examination Galloway decides he had better run all the boats through. This he does without unloading anything and without any trouble. I do not quite understand his hesitation about letting each one handle his own boat, unless it is because of his unqualified confidence in himself. He and I have been together a good deal, and this is the first time he has ever assumed any attitude of guardianship. Heretofore he has always taken it as a matter of course that I would do my share and look out for myself. At 10:25 we arrive at a bad rapid where we portage the loads about two thousand feet while Galloway brings the boats through. This is the worst rapid we have encountered, because of there being so many large rocks in the channel. The rapid hugs the right wall very closely. Below it is a beautiful crag, probably fifteen hundred feet high, crowned with a rectangular top, evidently of very resistant rock, doubtless limestone, since it has apparently supplied the great masses that choke the river channel.

At 12:30 P.M. we come to another bad one where the channel is again filled with rocks. Here we portage the entire loads about five hundred feet while Dubendorff gets lunch. This is probably the one which Powell calls Hell's Half Mile. The boats are taken out and over the rocks for one hundred and fifty or two hundred feet. This is quite a job, but is finished at 4 P.M., when each one runs his empty boat down to the head of the next rapid, which Galloway says is too bad to be run except with partly empty boats. So we portage half the loads to the foot of this rapid. Sharp fits another oar to replace one he accidently dropped into the water and lost, then he helps carry the stuff. It is a most difficult job because we have to climb a high talus on the right that is lying barely at the angle of repose and starts to slide at the slightest provocation. It is interspersed with various low-growing cacti, "pincushion," et cetera, and Sharp in trying to save himself from slipping with the sliding rock unfortunately sits down on one of these bunches. He never swears, but I am sure he now realizes the painful limitations of a wholly polite vocabulary. All of us feel more or less "stuck up" because of accidental contact with these prickly plants, but none so much as Sharp.

While we are engaged in portaging half of the loads Galloway runs the boats through and we all turn in as quickly as possible after the task is done. Dubendorff and I heat some soup and take a cup each. But we are unable to retain it—too much used up, I guess.

Friday, September 24, 1909.

Galloway finds Sharp's oar just below camp. Here the river runs east and west for a short distance. The cliff to the east is probably twelve to fifteen hundred feet high and composed chiefly of red-gray sandstone, apparently capped with a heavy bed of limestone. Just now, at 7:58, the sun breaks over its top, very bright and warm. We start at 8:40 and at 10:20 we stop above the mouth of the Yampa. Soon Lodore Canyon will

be behind us. At 11 o'clock we reach the mouth of the Yampa River, Echo Cliff, and Echo Park (Pat's Hole), where we stop for lunch.

Off once more at 1:10 for Jones Creek, where we arrive at 3:15 and go into camp in a delightful bower of box-elders. No tents are needed. Indeed, there is no room for even the small ones we have. At 5:30 Galloway comes in with thirty-one trout, which I fry for supper. We eat all but three. The sky is clear, there is no wind, the weather is perfect; and everyone is as happy and full of good spirits—and trout—as he can be.

Saturday, September 25, 1909.

Galloway and Dubendorff go up the creek fishing. Sharp takes his gun and goes along, there being a great many fresh tracks all over the flat, while I stay in camp to patch my trousers, luxuriating in the sunshine and comfort of the day. The autumn colors in the trees are softened by the pale green of the rabbit brush, here and there breaking into sprays of golden blossoms. Beneath them grow low yellow and purple flowers. And all blend into a harmony strangely in keeping with the ruggedness of the canyon walls and the restless, hurrying water that plays so rough and yet so fair a game.

The note of a bluebird comes intermittently from the thicket that fringes the river's lip, while the sun creeps around the rim of the crag that hides it nearly all the time. I see a water ousel in the creek and afterward hear him in the thicket. Last night, beginning at 8:25 and continuing until three this morning I saw a beautiful sight. The contour of the top of the cliff on the south side of the river coincided almost exactly with the position of Mars as seen from the spot where I lay, and as the radiant planet seemingly advanced westward in the sky, it was alternately hidden and unmasked by the serrations of the cliff. There were seventy-five or eighty of these obscurations and apparitions before it passed wholly from sight.

The creek appears on the map as "Bishop Creek," but the

local name should always obtain, and Galloway says it is known only as "Jones Creek."

At 12:20 Galloway, Dubendorff, and Sharp return with ninety-eight fine trout which we dress and salt. Then after a cold bite we start at 1 P.M., reaching the mouth of Whirlpool Canyon at 2:25. Here the rocks through which the river has cut its way flex sharply downward and disappear while the stream meanders into the open country five or six miles and then doubles back until it reaches the foot of the fold again, not more than fifteen hundred feet from the mouth of Whirlpool Canyon.

At 4 P.M. we camp below an island in Island Park in an open grove of large cottonwoods. Mr. Arthur Ruple, who has cattle in this region, rides over to see us, accompanied by two boys on another horse. They decline to join us at supper and soon leave to cook their own. While the rest are washing dishes I cook the remaining trout about half-done so they will not spoil. Then we wrap them in paper and gunny sacks for future use.

6 P.M. Sky clear, no wind. The air is not at all chilly. It is a radiantly glorious night.

Sunday, September 26, 1909.

Galloway caught one beaver last night.

We start at 8 A.M., stopping about thirty minutes at an island to see if we can find any deer, but fail to do so. The fold through which the river emerges from Whirlpool Canyon bends westward, south of Island Park. The river, after flowing along its base for two miles or so, turns abruptly through ninety degrees and cuts directly to the axis of the uplift. This it then follows for six or seven miles, forming Split Mountain Canyon, which we enter at 10:25. At 11:30 we reach a heavy rapid where we portage two thirds of the loads twelve or fifteen hundred feet while Galloway runs the boats through. Then we get lunch.

We are off at 1:20 and run out of the canyon at 5:25, then make camp on the right side on a gravel bar. The boats are taken

out. Skegs are put on again so they will handle more easily in the less turbulent water we shall now find for some distance.

This afternoon, as we are approaching the last bad rapid in the Canyon, Dubendorff's left oarlock comes out of its socket, leaving him practically helpless in a very precarious situation. But Coggswell reaches forward and seats the pin in its socket just in time to prevent the bad wreck which otherwise would surely occur. It is a most timely instance of presence of mind under disconcerting conditions, and I am glad to record it, even though it is the first instance wherein he has shown a lively interest in doing anything.

Monday, September 27, 1909.

Up at 5:30, a little early, in order to reach Vernal to-night, if possible. Getting started at 7:35, we reach Mr. Thorne's ranch at 9:45. His little boy, Lewis, shows us into their melon patch where, by permission, we help ourselves to all we care to eat and all we wish to take along.

Just below the mouth of Red Wash we pass the Dinosaur National Monument, where a party from the Carnegie Museum in Pittsburgh is digging out the fossil skeleton of a large dinosaur, a job that has already taken them two years and isn't finished yet, so Galloway says. We leave here at 10:37 and stop for lunch about a mile above Jensen. Off at 1:05 and at 1:35 reach Jensen, from which place I send a telegram home by phoning it to Vernal. We leave Jensen at two o'clock and reach the Ferry at Alhandra at 5:10. Then we go down to the Uinta Co. stage station, where we put all our "traps" into a barn and lock them up. Then we cross the river and go to Vernal, sixteen miles distant, a Mr. Warner by arrangement from Jensen, having come after us.

We reach Vernal at 8:25. By good luck we find the post office still open, but I get only one letter and one postal from home, both dated the 12th. We stop at the Alwildy Hotel, only too glad to turn in for the night.

This afternoon Galloway killed a goose, which we send out to Mr. Gibson's.

Tuesday, September 28, 1909.

I sleep fairly late and then after breakfast write letters, send some telegrams, and do some shopping—shoes, tools, et cetera. At 12:30 I go to an "Old Folks Meeting" by invitation, and enjoy it very much, I being classed among the old folks. Then at 4 all of us go to Mr. William Gibson's for six o'clock dinner, where we have a delightful time. He is a fine old gentleman, one of those who crossed the plains in the early days. In fact, thereafter he teamed between Salt Lake and the Missouri River. He relates many interesting incidents of those strenuous times.

The early travelers across the treeless plains of necessity used "buffalo chips" instead of firewood. Consequently the supply of this fuel was soon exhausted for a considerable distance along each side of the line of travel. Mr. Gibson therefore on his eastward trips loaded his wagon with dry wood and at certain intervals buried a supply, erecting a cross in order to simulate a human grave, thereby avoiding the chance of anyone disturbing his firewood, which he then exhumed and used on his westward trip. He has a medal presented by the State of Utah for his services in fighting Indians during their many retaliatory raids and depredations on the outlying settlements.

We return at 9:45 and go to bed after a very pleasant day. While we are gone the table in my room has been loaded with the most luscious apples I have ever seen. One measures fifteen and three quarter inches in circumference, and there are many others nearly as large.

Wednesday, September 29, 1909.

Up at 5:30 and write some letters before breakfast. We spend the rest of the forenoon in visiting with new acquaintances, everyone being very friendly and hospitable. In the afternoon Dubendorff takes me out to see some orchards and the countryside in general.

Thursday, September 30, 1909.

Up at 5 A.M. Spend the forenoon in writing letters and getting ready to start, which we do at 12:30. We pick up Dubendorff en route and reach the river at 2:45. We reload our boats and make camp on the right bank a little way below. Galloway and Dubendorff go after the pelts that were cached above Alhandra, but having difficulty in finding them, do not get back until late.

During the afternoon I tack leather around our oars where they are seated in the oarlocks and fix things up in general.

Friday, October 1, 1909.

Up at 5:40 to finish fixing Sharp's oars. At eight Mr. Gibson, Mrs. Gibson, and their whole family arrive to see us off. Three other carriage loads also come. At 10:30 a lunch is spread and all of us have a regular feast. Then at 11:10 we say goodbye and start. In about three quarters of an hour we reach Mr. Slaugh's ranch where by invitation we stop and are treated to some very fine melons. He also gives us all we can take along to eat on the way. We make no noon stop, but at 2:45 we land at the foot of an island where we take out three of the boats and nail sheet iron strips along the corners of the bottom and along the side seams. The boats are not clinker built, the side planking being butt-jointed. This takes Dubendorff and me until 5:45, while Sharp gets supper. Galloway goes to set traps. I make a few observations because of having hit my thumb with the hammer. The nature of these will probably be understood by everyone who has done the same awkward trick.

Through this valley, Ashley, the topographic features are impassive, save as to the effect of erosion. The few exposed edges of the strata are undisturbed and practically coincide with the grade of the river. There are many high gravel bars, all said to carry gold. This they probably do, but not in paying quantities.

Sharp discovers that the big tree under which we are

camped is a "bee tree," but as we supplied ourselves with honey at Vernal there is no occasion to disturb the bees.

Saturday, October 2, 1909.

Up at 5:30. Galloway goes to take up traps. Sharp got up at 2 A.M. to shoot ducks. The moon was so bright he thought it must be morning. We start at 8:35, taking up the traps below camp, but find nothing in them. The river banks are thickly covered with cottonwoods, willows, squawbrush, and other undergrowth, the squawbrush foliage in especially brilliant autumn colors because of recent frosts. The lower strata near the water continue undisturbed and contain several red beds or laminations, stained with iron. Sharp takes some specimens. We try to stop where there is a lake near the left bank, but as I get into quicksand up to my knees, we go on until 12 o'clock and then stop on the right bank. Here Galloway nails iron strips along the corners and sides of his boat, and here we have lunch.

In the distance to the northwest the highest peaks of the Uintas rise into view, "Old Baldy" flecked with snow, and all the peaks wonderful as seen through the haze of the intervening distance. As Galloway is not quite through when we finish lunch and as I do not feel especially well, I drift on ahead of the others. A bad head wind springs up and makes such hard work that I tie up among the willows on the right bank, where there are many beaver "sign." When the others come along we go about half a mile farther and camp under a large cottonwood at 4:40. Galloway sets his traps. Away to the northwest are the blue tops of the mountains. It is storming there. It is also storming to the south and west, so we will probably get a taste of it before long.

Sunday, October 3, 1909.

It rains a little during the night but the moon shines brightly in the east throughout the shower. I get up to see if there is a lunar rainbow, but there is none, the moon being too high.

Caught one beaver. Off at 8:40. At 11:40 we stop for lunch on a high flood plain on the right side. Four ducks are flying past in single file. I get all of them with the repeating shotgun. They will help out our larder.

Off at 1:10 and at 2:55 reach Ouray, where we post letters, buy a ham, and take some pictures of Indians at the post trader's. Then we go on, at 3:20 passing the mouth of the Duchesne River, and the mouth of the White River at 3:50. We see many beaver sign, including eight slides or wood roads close together on the left bank. A storm is coming. We therefore hunt a camping place and stop on the left bank at 4:45, none too soon, for in about thirty minutes, just as we have the tents up and supper started, a high wind brings first hail and then rain. But during a lull we finish cooking supper and eat. Then it begins again. Now, at seven, it is blowing and raining hard. But here in the tent it is cosy, with a candle tied to a stick stuck into the ground. We are all busy writing up notes.

Monday, October 4, 1909.

The sun rises beautifully bright and the morning is glorious. Galloway caught two beaver. We start at 8:15. About a mile below camp we pass a place where a new copper mine is being opened and a mill erected. We stop for lunch on the right bank at 12:15, having halted about twenty minutes for Galloway to kill a goose. Here we eat another of the melons Mr. Slaugh gave us, and are off at 1:05, rowing steadily until 4:25, except for about thirty minutes lost in trying to get another goose. Then we camp on the sandy right bank (there being no grass) among some old cottonwoods. While Galloway sets traps I sew ropes into the corner seams of our tents, a hard job. That is, I sew in three and then Sharp does the fourth one while I help get supper. Galloway stretches two beaver skins and I stretch another one while he fixes his oars by the firelight. This afternoon we passed some men who rode out into the water to say "Howdy" and tell us that we "can't go very far in them boats

because there are rapids and things below." But when I tell them that Galloway has been through here several times they say, "Oh, if that's him, he knows more about it than we do."

The walls are considerably higher than yesterday, the strata quite varied in color, banded in yellow and gray, green, black, red, and variations due to intermingling of these. The beds are nearly horizontal, rising slightly to the southeast, but generally undisturbed by any folding. The thicker ones show cleavage planes, usually at right angles to each other and about forty-five degrees from the vertical. These appear to a quite marked degree. Many of the strata are stained with iron and some with copper. This forenoon, too, we pass a vein of Gilsonite, which Galloway discovered several years ago. It is only about ten or twelve inches thick and is in a nearly vertical position.

Tuesday, October 5, 1909.

Galloway caught three beaver last night, all small ones. Off at 8:20 and soon enter Desolation Canyon. At 11:30 we pass the first riffle, just below which a Mr. Nutter, an old friend of Galloway, comes out to speak to us, he happening to be here looking for cattle. At 12:10 we stop on the left bank for lunch. The canyon walls seem to be seven or eight hundred feet high, of light-colored sandstone and shales characteristic of early Tertiary rocks. Off at 1:50, rowing steadily until 5:50, at one place finding a cow almost submerged in quicksand. As there is no chance to get her out, Sharp at my request shoots her. We camp on the left bank on a flat covered with greasewood.

Wednesday, October 6, 1909.

Galloway caught two beaver. It rained a little during the evening, but the moonrise was magnificent, touching everything with the mystic enchantment of the night. I awoke Sharp to see it, but somehow it did not appeal to him as much as his bed.

Last night he and Galloway discovered they were distantly related. Surely this is a small world.

The walls here are very rugged, but generally slope back at an angle of about thirty degrees from the vertical as they rise from the flood plain. They are interspersed with beds of red rock, stained with iron, and green rock, stained with copper. These are not very thick or persistent, coming in and pinching out in the most erratic manner. At times there appears above these a thin stratum of a violet color, and in one place a pronounced purple.

We start at 8:37 and pick up a beaver from a trap below camp, and then row down some distance where Galloway expects to find quite a colony of them. On the left side about halfway down we pass a band of wild horses. Greatly frightened, they try to climb the sloping walls but cannot do so, and then stampede down the talus. Soon, unable to go farther, they turn up stream in great confusion. We reach the place Galloway has in mind at noon, but find no signs of beaver. We stop and eat our lunch, which we probably would have done even had the beaver been here. I fix Sharp's oars and mine, and Galloway patches his boat, while Sharp and Dubendorff take off the skegs. Then at 3:40 we start and pass one bad rapid and several lesser ones. Sharp has a mishap with one oarlock just before we reach the bad one, but gets to shore all right. He fixes it by tightening up a set screw, then follows the rest of us through. We proceed about four miles and at 4:30 camp on the left bank between two small rapids. To some extent box-elder is replacing the cottonwoods on the flood plains. The strata rise generally to the south. The light-colored and variegated series so persistent in Ashley Valley has apparently risen to fourteen or sixteen hundred feet, capping the whole country as far as we can see from the river.

Thursday, October 7, 1909.

Off at 8:20, making good progress until 11:35 when Sharp sees a mountain sheep. Galloway lands on the opposite side and shoots it at about three hundred yards. Then he, Sharp, and Dubendorff climb to the top of the bench where it is and bring

it down. We go on at 12:10, but only a little way until we find a place to camp on the left bank, under an unusually large branching cottonwood. Here we skin the sheep, cut up and pack the meat, fry the liver for lunch, and go on at 2:10.

At 3:05 we reach a nasty rapid about three miles above the canyon's end. Galloway says he has never run this before, but that at this stage of water it looks all right. Accordingly, we start, Galloway first, then Sharp, then I, and Dubendorff last. Galloway goes through as planned, but Sharp gets a little out of place and is caught on a rock just below the take-off. I am able to clear him by swinging out into the heavy current in mid-channel and go through without trouble, as does Dubendorff also. Then we all clamber back along the left shore to help Sharp, whose boat has swung sidewise to the current and is now held between two rocks. He is able to toss most of the contents to us. The heavier things, as well as himself, we pull over with a rope, but lose one camp outfit and some provisions in the effort. Excepting the contents of the rubber bags all is thoroughly soaked. Then we set about freeing the boat, but cannot move it with either bow or stern lines. Fortunately a small tree five or six inches in diameter is nearby. We cut this, strip it of branches, and using it as a lever succeed in lifting the boat so that it floats between the rocks. Though it wedges again a little lower down, we manage to get it free, and down to the foot of the rapid. Here driftwood is plentiful. We build a large fire against a convenient ledge and soon have everyone and everything pretty well dried out. While we were trying to free the boat from the rocks, I clumsily fell into the water, but got out with little difficulty.

Friday, October 8, 1909.

Galloway and I patch Sharp's boat where it was split on the rocks. Off at 8:40 and at 9 o'clock we stop at McPherson's ranch where we are treated to peaches, pears, and apples from the trees, also watermelons, cantaloupes, and tomatoes from the vines, all of the finest quality and flavor. The unfailing

courtesy received from everyone we meet is in fine contrast to the scant consideration sometimes accorded wayfarers in the East. Leaving there at 9:40, we at once come to a very shallow rapid where we have to carry everything probably two hundred yards while Galloway wiggles the empty boats through, between, and over the rocks. He is so dexterous that one would not be surprised to see him run a boat on a heavy dew if it were necessary.

Just where Desolation Canyon ends and Gray Canyon begins we find a very swift rapid where all the water goes through a chute about twenty-five feet wide along the right wall. Dubendorff takes Coggswell across to the left side and then we run it, though Sharp gets too close to a large rock on the right and narrowly escapes being wrecked again. Dubendorff also gets too far over, but not dangerously so. We are out of Desolation Canyon at 11:45, and have lunch on the left bank.

Off at 1:46 and run down to a box rapid at 5 P.M. where we portage to a half-way point and make camp at the mouth of a little side gorge on the right while Galloway and Sharp line the boats to the first eddy below camp. Here we will load up in the morning and run the rest. This canyon differs somewhat in general character from Desolation. The walls are not so abrupt and are quite gray as compared with those of the latter.

Saturday, October 9, 1909.

Off at 7:35 and at 11:20 emerge from Gray Canyon. A little way below the box rapid we see a small seam of coal, about eighteen inches thick at the water's edge on the left side. It rises gradually and thickens slightly until at the mouth of the canyon it is probably five or six hundred feet above the river and several feet in thickness. A heavy bed of sandy shale underlies the seam. The whole exposure beneath it down to the water indicates there are other seams below. In the western wall at the end of Gray Canyon, especially at the base of Gunnison Butte, are many beautiful joint or cleavage planes of great extent, as fine and smooth as I have ever seen. They

glisten in the sunshine as we pass. There is a bad rapid just above which we run at 11 o'clock and stop for lunch at 11:20 on the left side.

After putting on skegs we are off at 1:20, reaching Green River, Utah, at 3:40, where we land just above the railroad bridge. According to Galloway's estimate, we have made about four hundred miles in twenty-four days on the river. And if our luck keeps up, we will be at Needles in time to get home for Christmas.

Sharp, Coggswell, and I go to the railroad hotel to sleep, while Galloway and Dubendorff camp by the boats.

Sunday, October 10, 1909.

I put in the day writing letters. Galloway packs and ships the beaver pelts, also the sheep skin, to Chicago. Films are developed, some good and some bad. The exposed ones are shipped home and from the supply of unexposed films awaiting us in the express office we take enough to last us until we reach Grand Canyon, shipping the remainder to that point and hoping to find the package on arrival.

Monday, October 11, 1909.

We devote the day to fixing the boats, getting needed supplies, et cetera, in order to start to-morrow, and then go into camp at the river.

Tuesday, October 12, 1909.

At 9:30 we are on our way, stopping for lunch on an island on the right side at 12 M. I shoot three ducks, of which there are a great number. Off at 1 P.M. and pass the mouth of San Rafael at 3:30. This is about twenty-five miles from Green River. We enter the gate of Labyrinth Canyon at 4 P.M. and at 4:45 stop for camp on a high bank on the right. Ducks still being very plentiful, I shoot a canvasback. Where we are camped lies a cottonwood tree measuring twenty by thirty-one

inches at the stump, cut down by beaver. This clearly shows that the last colony here was driven out by lack of food, since they would not have cut so large a tree had not the supply of smaller ones been exhausted.

Wednesday, October 13, 1909.

Start at 7:30 and stop for lunch on the left side near the end of Little Bowknot bend at 12. Off again at 12:45 and reach the neck of Big Bowknot bend at 1:30. We let Coggswell off to get pictures. It being but a few hundred feet across the neck of land at this point, he walks over to await our arrival. We set about a six-mile pace and maintain it as nearly as we can all the way, the current being practically constant. It takes us eighty-five minutes to get around, which would equal a little over eight miles. Dellenbaugh says it is five and one half. We think he is wrong.[1] Then we go about eight miles to the mouth of Hell-roaring Canyon where, according to information given us by Mr. Wheeler at Green River, we find an inscription on the rocks three hundred and fifty yards up the canyon from Green River, and probably twenty-five feet above the bed of the creek. Dellenbaugh says this inscription is in Bowknot Bend. However, I am under the impression that he did not know of its existence in 1872, but heard of it afterward. It was evidently picked into the rock face with the end of some dull tool or punch (see Part Three, Plate 39A.)

The strata are rising slowly to the southeast. Some mineralized blankets seem to be interlaid among the sandstone beds, which are generally of a light gray color. We are camped at the mouth of Hell-roaring Canyon, which we reached at 4:45 P.M.

Thursday, October 14, 1909.

Start at 8:30. At 9:30 Sharp and Galloway stop to get some samples of rock on the right. Here, as for many miles back, the upper sandstone ledge is very massive and its face is

[1] A survey made since then shows it to be seven miles, and so both of us were wrong.

usually vertical as well as columnar. These beds were named the Orange Cliffs by Major Powell.

A short distance below Hell-roaring Canyon a large canyon comes in from the eastern side. Its vertical walls are very imposing.

The water in the river is unruffled by wind or current. The sun is very hot and the sky away from the sun intensely blue. Below the upper stratum of sandstone and protruding through the talus which begins at its base are several beds of vari-colored material. The greater number apparently contain iron. Between these and the sandstone is a stratum varying from waxy yellow to a dark brown, and another that at times is very green, then changes to a pink and in one place to a purple, but none of these strata is persistent. At one point in the west wall we see a large lenticular mass, very yellow and friable on its exposed surface, that looks like carnotite.

We stop for lunch on the right bank at 11:40. Here the opposite wall is composed of thin laminations up to about twenty-five feet or so from the water, then alternate talus slopes and hard strata receding backward and upward to the heavy columnar sandstone, probably four hundred feet above the river. Off again at 1:10, making camp at 5:20 at Yokey's flat, on the right side.

This afternoon we stopped about thirty minutes at "Townsite Flat," by invitation of Mr. Anderson at Green River, and helped ourselves to some melons, turnips, rutabagas, and one little head of cabbage, which we boil (excepting the melons!) with the last of the mountain sheep, which has now become very tender—too much so, according to Sharp, who declines a helping. We passed the Buttes of the Cross this afternoon. A massive stratum of light gray sandstone has come up within the last three or four miles and is now seventy-five to one hundred feet above the water.

Friday, October 15, 1909.

We had the last of our mountain sheep for breakfast. It was a little "high," and therefore very tender.

Off at 8:30 and pass a fine cliff dwelling tucked away in a recess in the vertical face of the wall. This is farther north than any similar dwelling of which I am aware. It is in a good state of preservation and of great interest. We come to "Cleopatra's Needle" and "The Sphinx," two very picturesque results of weathering just above the water edge on the left side. Near "Turk's Point" we stop for lunch on the right among squaw-brush. Coggswell forgot our camp grate this morning. It was not worth very much, but was mighty convenient.

We are just below where the first limestone comes up and as we are nearing the junction our anxiety results in a race that rages around bend after bend until 3:30 when we suddenly come to the mouth of the Grand [1] in the same relative position as when the competition started. Everyone is pretty well winded, but amused at the result of the contest. As one comes down the Green the mouth of the Grand cannot be discerned until he is within one hundred yards or so. Just below we find a flock of greater snow geese and I, being in the lead, am lucky enough to get one as they rise from the water. Then we drop down to the head of the first rapid three or four miles below the junction and camp on the left side at 4:45.

The character of the canyon changes at once below the Grand; but it's no use to attempt any extended description, because the photographs will or should show all that. Here we find signs of a party consisting of two men and a half-grown boy just ahead of us. Footprints in the sand and around their recent campfire clearly indicate not only the nature of the party, but also that they are not over two or three days ahead. They have but one flat-bottomed boat—and that not a very large one. The bottom is not protected with sheet metal and already carries some patches.

We take off the skegs and fix corner supports for canvas fenders around the cockpit of each boat. We tack the fenders on at the bottom and fit rings to the top edge that shall slip

[1] The name of the river above the mouth of the Green has since been changed from the Grand River to the Colorado River by the Committee on Geographic Names.

over and into a notch cut at the top of each corner stake, so that the fender may be easily raised or lowered as circumstances require. When raised it is eighteen inches high and we expect it will keep out a great deal of water in the more turbulent rapids that are surely ahead. The material used is heavy bed ticking, bought for the purpose at Vernal. We double it in order to make it as effective as possible.

Saturday, October 16, 1909.

We work all day on our boats, but are not quite finished at night-time. Hope to get away to-morrow forenoon—tired.

Sunday, October 17, 1909.

I catch a six-pound "whitefish" or Colorado salmon. The flesh of this fish has a peculiar characteristic in that if fried soon after being caught the muscular contractions cause the pieces to wriggle about in the skillet in a manner astonishing to anyone not accustomed to it, so much so that the Adam's-apple of one member of the party tried to turn a somersault when he was offered a helping. Still, the fish, though full of bones, is not unpalatable.

We start at 11:20 and run down to rapid Number Six, where part of the loads is portaged and boats lined possibly one hundred yards and then reloaded. We go on to a ledge of calcite on the left for lunch, at 12:35.

Here also we see evidence of the party ahead. It would seem that they are prospectors, judging from the number of fresh pick marks in the rocks, but as there is little or no mineral in these carboniferous measures, they are probably inexperienced. Then we go on at 1:40 and run everything to rapid Number Eighteen, where Dubendorff gets caught on a rock on the left side of the channel. His boat swings around, strikes another rock with its bow, and comes down bottom up. Dubendorff gets out all right after a somewhat thrilling experience among the rocks underneath the overturned boat. Galloway catches the boat, Sharp the camera and tripod, while I pick up the bedding,

tent, and other floating articles. But Dubendorff's vest (containing his watch, et cetera), his hat, and two days' exposed films are lost, as well as sundry other articles loose in one compartment of his boat which, he not expecting an upset, was unfortunately open. Cogswell neglected yesterday to seal up the exposed films as directed and to turn them over to Galloway or me. The mix-up occurs at 5:15 and we make camp immediately below, luckily finding plenty of driftwood to make a big fire and dry everything out. I succeed in taking the Zeiss-Tessar lens, including the iris diaphragm, apart, cleaning as well as drying everything completely, and then reassembling it all right —not much of a job under other circumstances, but rather difficult here where patience is decidedly at a premium, considering what made the task necessary.

It is mighty lucky that Dubendorff had his life belt on. Otherwise he would surely be dead. Coggswell was walking around the rapid when the spill occurred. My boat is leaking badly, so I must fix it in the morning. Galloway shot two ducks this afternoon.

The moon and Venus are close together in the west. The Andromeda nebula is clearly visible to the unaided eye in this atmosphere and, nearly overhead, the Swan is flying southward along the glittering star-strewn depths that throb with the light of countless suns.

Could the glorious pageant of the stars be seen but once in, say, fifty or one hundred years, how eagerly, how impatiently would mankind look forward to its coming and what legends, what poetry would cluster around its past apparitions. But since its splendors are disclosed by every sunset they hold no interest, save for the few to whom each succeeding night brings a newer and deeper enchantment.

Monday, October 18, 1909.

We are up at daybreak and begin patching my boat by nailing a strip of tin with a double strip of cotton cloth covered with white lead, underneath it, all the way around the lower

seam, then clinching the nails on the inside of the boat. We finish at noon, have lunch, and get started at 1 o'clock.

We run the first rapid, Number Nineteen (from the mouth of the Green River) then come to a bad one which is divided by a rocky island. On examination Galloway decides to line the boats. This is done by landing at the head of the island and working them down its west side. A little way below is one still worse because of large rocks and a heavy descent. Here the loads are portaged while Galloway and Dubendorff "line" the boats about one hundred and fifty yards. We load up and drop down to the head of Number Twenty-two but as it is 4:40 we cross the river and go into camp on the left side. We are all too tired to put up tents. The space is small, anyway. Estimate having gone but two miles to-day.

Tuesday, October 19, 1909.

6 A.M. weather mild, no wind, sky clear. Galloway has to fix his boat a little, so we do not start until 8:30. He and I run the first rapid, Number Twenty-two. He then brings Sharp's boat through and Dubendorff follows, after which we come to a very rough one where the party ahead took its boat out for a little over a hundred feet. We cross over and line down the other side after portaging the loads. Then we come to the head of Number Twenty-four, which is fully as bad as the one above but has a channel among the rocks on the left side where Galloway and I run it. Then he goes back after Sharp's boat and he and Dubendorff come through. Dubendorff goes out into the big waves in the middle of the channel and gets through all right, though he is thrown off his seat and nearly upset.

Standing on a large rock at the foot of the rapid, I watch Dubendorff come through. He has said he would not run among the rocks. As his boat sinks into the trough below the first big wave, he goes wholly out of sight. Several times thereafter only his cap is visible. He doesn't like the looks of the rocks, and I don't blame him.

Just below the head of this rapid we find a wrecked boat,

evidently belonging to the party just ahead, and on a rock nearby a blue serge coat spread out as though to be dried in the sun. Near the coat is a crude oar and a push pole. The coat is still damp, and the rock underneath it is wet, showing that it could not have been there over twenty-four hours—there having been no rain. Inside the coat is this mark

"O. W. Hadley
Kellogg & Wardner
Idaho."

Evidently this is the name of the merchant who sold it. Nothing is found in the pockets. We bring the coat along. The boat is irrecoverably lost. After photographing the scene in detail we go on in the hope of overtaking the wrecked party and helping them out in their extremity. We find no further trace of them. About a quarter of a mile below, the eastern wall seems somewhat broken down and might possibly be scaled. To lose one's boat in such a place is practically to lose one's life, because even if it were possible to climb out, the country being a grassless, treeless, waterless waste, deeply scarred by side canyons that are generally impassable for a long distance back from the river, a stranger on foot and without maps or provisions, especially water, could not possibly reach either Monticello, Moab, or Dandy Crossing, the only places where help might be found.

They were evidently unacquainted with the seriousness of the undertaking. Otherwise they would not have started with such a crude outfit. The boat was poorly built, not decked over at all. The wonder is that they got as far as they did.

We run Number Twenty-five and stop on the left side at 11:50 for lunch. Off at 12:45 and run everything down to the head of Number Thirty-three, where at 4:30 we camp at the mouth of a side canyon coming in from the east. It is quite large and has beautifully terraced walls. In fact, it is scarcely less impressive than the main gorge itself. There is a great deal of calcite here. Part of it breaks up into rhombohedrons quite readily when sharply struck. Possibly some might be ob-

tained in a pure enough state to be used for optical purposes.

We have passed a number of places to-day where the river is boxed in but have seen no further sign of the wrecked party. The unwelcome conclusion seems to be that they are lost. Galloway says the nearest settlement is about forty miles in an air line toward the La Sal Mountains. We think we have passed to-day that point of the river which Stanton named "Hell's Half Mile," but he was off in the distance, because there is more than a half mile. Possibly that's the hell of it. Just below is a rather sharp rapid that kicks up quite a rumpus in the matter of noise.

Wednesday, October 20, 1909.

Off at 8:20, portaging the loads about six hundred feet. Then Galloway and I come through, after which Galloway and Dubendorff run it. Thereafter we run everything until 11 o'clock, when we see a few sheep, and being short of meat, shoot a young one. These sheep have probably strayed into the canyon somehow, and will doubtless be killed by wolves, anyway. We then stop for lunch under a couple of hackberry trees at the mouth of a narrow canyon coming in from the right. When we were breaking camp this morning Sharp found a little goldstone watch charm in the sand near the river and kindly gave it to me.

Off at 1:05 and as the first rapid, just below where we lunched, has a fairly clear channel with high waves and as we wish a picture of a boat in heavy water, I purposely go out into the thickest of it, the net result being a fine ducking. The boat being unable to rise over the refluent waves just below the "take-off," they sweep over its stern, tearing away the canvas fender, taking everything movable out of the boat except me. Those on shore say I am completely out of sight three different times. For a few seconds I have the greatest difficulty in staying right side up, but soon get to shore on the right, where I pull the boat up on a sand bar and dump the water out of it and then go on. This will be the last time I voluntarily invite

an upset or possibly something worse, because when a boat is once out of control there is no telling what may happen.

After this we run eight more rapids before coming to a short but very turbulent one full of rocks from a side canyon on the east. Here the main volume of the river is forced against the wall on the west and, all in all, it is a bad one. We portage the loads one hundred and fifty yards. Then Galloway and I come through, after which Galloway and Dubendorff run it. At 4:45 we make camp on the left a little lower down in a beautiful spot. The water is as placid as a lake, without a ripple. The air is a trifle chilly, temperature about 50, and sky clear. The canyon walls are massive, dignified, and reposeful. The silence is impressive, the whole scene without a single hint of the ceaseless turmoil of the unquiet river both above and below us, while overhead, in indescribable glory, passes the wonderful procession of the stars.

Before going to bed I strip off and take a cold bath (it would be difficult to take any other) and a good rub, and put on dry underclothing, having been wet all over since noon. My outer clothes are now fairly dry. We have safely passed fifty-two rapids in this canyon. Tomorrow should see us out of it. Today the strata have run fairly parallel with the grade of the river, the walls as usual being beautifully terraced except where they are vertical or nearly so. There is little vegetation, aside from a few willows and hackberry trees. The talus generally comes down to the water, there being but few small flood plains. This talus consisting principally of broken limestone and sandstone, there is small chance for plant life. We hope to reach Dandy Crossing tomorrow.

Thursday, October 21, 1909.

Off at 8:20 and run the first rapid without much difficulty, and then come to the last bad one in this canyon. It is at the mouth of Dark Canyon, which comes in from the left, and is a rough one, sure enough. Here we have a hard portage, leaving nothing at all in the boats while Galloway and Dubendorff line

them. By 11:45 we have replaced the skegs, reloaded the stuff, and are on our way again. We pass four light rapids before stopping on a high sand bank on the right side for lunch at 12:45. While the others are attending to that job, I go on down the stream as far as I can, looking for the "D. Julien" inscription that Stanton reports having found somewhere in this neighborhood. I have no success. Probably I have missed the location, as it is a long time since he told me. All of us have kept our eyes peeled for it during the last two days, because I would like to photograph it.

Off at 1:55, finding but two more moderate rapids before reaching the mouth of the Fremont, or Dirty Devil, River at 3:55. Just above here are a number of warm and hot springs of sulphur water, but it probably contains other ingredients because water from different springs tastes differently, at least from such as we sample out of curiosity. At 5:10 we reach Dandy Crossing (Hite Post Office).

Here two old friends of mine, John Hite and Fred Gibbons, have been living alone for many years, holding down mining and placer claims.

John has gone up White Canyon for a month (he went yesterday) to do some assessment work, leaving Fred the only one here. Fred tells me it is over two years since a wagon has been in. The mail is brought in on horseback, as are also the meager supplies required by the few prospectors in this region. We find more or less mail for each of us. Unfortunately, Sharp receives word that necessitates his return home. Gibbons tells us that a man will be up to-morrow evening from one of the placer bars below here on his way to Hanksville, sixty miles distant, for supplies, and that Sharp can probably arrange to go that far with him.

Friday, October 22, 1909.

Work on my boat to-day fixing a better method of holding the canvas ducking down over the forward and rear cockpits.

Galloway forges some staples for me, also making a new camp grate and mending his shoes. Dubendorff calks his boat.

About 4 P.M. the young man arrives with one saddle horse and two pack horses. He finally agrees to take Sharp as far as Hanksville.

Saturday, October 23, 1909.

Up at 5:10, as Sharp, who has to leave the party because of business reasons, wants to get an early start for Green River, one hundred and ten miles across the desert. He is off at 6:50 on horseback with a pack animal and one companion.

Sharp's boat is given to Fred Gibbons, as we have no further use for it, and it will come handy for him. Then, too, he has been very kind to us, hospitable to the limit of his possessions, even letting us have a sack of flour and some baking powder, though his own stock is very low.

We take some supplies that are to be left at points below and start at 7:35. At 10:35 we stop at Tickaboo bar, and go up the creek about a mile to call on Cass Hite. Here, as elsewhere, the most generous hospitality awaits us—melons, very ripe, and grapes fresh from the vine, also a large sackful of raisins to take along.

We swap a lot of talk about old times. He tells me that John Wilson is still prospecting in these parts, but is now hanging out at Hanksville when not in the hills, also that old Johnny Sullivan was killed some years ago by a shot that hung fire in a prospect hole.

Wilson is an old telegraph operator who in the sixties worked in Columbus, Ohio. He afterward was with the Union Pacific in the early days when black bears were so numerous they caused many interruptions by climbing telegraph poles and tearing the wires down in their hunt for honey, mistaking the resonance of the poles caused by vibration of the telegraph wires due to falling temperature for the humming of bees. Cass tells us he has a deal on whereby he expects to clean up $100,-000.00 for his placer claims, and I hope he does. But the ful-

fillment of his dreams has already been long delayed. Truly, hope springs eternal.

Off at 12:05 and at 12:40 we reach "Good Hope" bar, where we stop and leave some provisions brought down from Dandy Crossing. We find no one here. Then we cross and lunch on the east side at 12:55. Off at 1:55. The water is at least two feet higher than when Galloway and I were here before. We reach and stop at "California Bar" at 5:10, where Galloway goes out to the west wall and finds a great many hieroglyphics to which we were directed by a Mr. Mitchell whom I met at Vernal and who formerly owned and worked this bar. I landed above a little rapid but could not get through the willows at the edge of the water, so went on to where Galloway was. To-morrow we will stipple the hieroglyphics with flour in order to photograph them.

The moon, a little past the second quarter, is beautiful; Venus shines resplendent, it is a perfect night.

Sunday, October 24, 1909.

Last night while clearing away a place for my bed I found two pieces of old pottery (parts of a handsome bowl), and gave them to Dubendorff. This morning I find another piece, and as luck will have it they all fit together. At 7:00 we all begin to stipple the pictographs, some of which are much weathered and dim. The sun is so hot against the wall at 9:30 that we have to give it up and photograph without completing the stippling. On the way to the boats I pick up thirty-two more shards and give them to Dubendorff.

Off at 10:05. I kill a canvasback. Galloway shoots a widgeon. At 12:20 we reach the abandoned dredge, where I leave the roll of bedding and the box of grub brought down from Dandy Crossing. No one is here, but the proper person will find it on his return. Then we lunch and are off again at 1:15.

After a while the sky clouds up a little but clears again. We stop for the night on the left side, under an overhanging ledge.

I omitted to mention that we met Bert Loper yesterday forenoon above Tickaboo as he was making his way up the river. From his statements, which seemed straightforward, we gained the impression that he did not desert Russell and Monet on their trip down the canyons last year, as they claimed, but that instead *they* deserted *him*.[1]

A touch of pleurisy has been troubling my left side. Galloway prepares a plaster by melting some waxy preparation and spreading it on a strip of cloth. He sticks it on me, saying it will "fix" me. It probably will, but as he does not say which way, that is yet to be ascertained. Galloway says he buys it from an old man who has the secret formula for this magic plaster which he sells for a dollar a hunk. He, Galloway, has unbounded faith in it, and I would not hurt his feelings by seeming to doubt its efficacy. And yet to me it looks, smells, and behaves like ordinary grafting wax.

Monday, October 25, 1909.

Off at 7:30, hoping to make a good run to-day. At 9:30 we stop on the right bank at an oil spring to get a sample, leaving there at 10:10. At 11:25 we pass the mouth of the Escalante River, stopping at 12:35 some miles below, on the right side. Off at 1:20 and at 1:45 we pass the mouth of the San Juan, and then at 3:20 we pass Aztec Creek. At 5:35 we stop for the night on the left side. We kill two ducks to-day, Galloway one and I the other. Just before camping we find some beaver sign. Galloway sets three traps. About four miles below the Escalante we pass Hole-in-the-rock, where in the early days some Mormon emigrants with ox teams and wagons crossed the river on their way to establish the settlement at Bluff. How they managed to get down to the river from the west and then across and out on the other side would in itself make an epic story of those heroic days.

[1] This statement I have since amply verified. Russell certainly treated Loper *very* shabbily.

Tuesday, October 26, 1909.

Off at 7:55, reaching "The Crossing of the Fathers" (Vados de los Padres) at noon, Galloway and I getting nine ducks on the way. We stop about three quarters of an hour vainly trying to get a beaver in the river. Galloway caught one last night. At 10:30 we pass into Arizona, but will go into Utah again for a short way, and then we shall have Arizona on the left until we reach Needles.

At 2:45 we see a beaver in the water and Galloway keeps after it until he gets it. Then, as we find many sign, we go into camp at 3:10 on a very high bank on the right side. We are again in Arizona. This evening is delightful, as usual. I am still suffering a little from pleurisy, in spite of Galloway's plaster, and shall try the efficacy of hot water applications. The pain is not troublesome except when I draw a long breath or move in some particular way. Then it pinches badly. To-morrow we should reach Lee's Ferry. We have only about twenty-five more miles to go, according to Galloway. He remembers nearly every turn in the canyon. Although I also have been over this part of the river before it seems quite strange, though a great many features are familiar.

Wednesday, October 27, 1909.

Off at 7:30, we reach the mouth of the Wahweap at 9:30 and take several photos of the wall at its junction with the Colorado.

This is what Powell erroneously pictures as "Island Monument." It is also shown by Dellenbaugh in "A Canyon Voyage," but end-on, that is, in the same position as Powell shows it, in order to make it appear as a shaft or monolith, which it is *not.* Its average width in a northeasterly and southwesterly direction is quite equal to its height. Looked at from the only position in which it can be seen as Powell shows it, it would be impossible to see the moon behind it as it is shown in his illustration, because one is looking northeast.

We reach Lee's Ferry at 12:35 and go into camp among the willows opposite John D. Lee's stone fort which he built and inhabited for some years after the Mountain Meadow massacre. For his participation in this atrocity he was afterward legally executed on the scene of his crime. The fort is deserted, as is also the ranch house that was occupied by Mr. Emmett when we were here before, he having sold out to a cattle company and gone to Kanab, so Mr. Ryder, a cowboy whom we find here, tells us. A careful search for the supplies we were expecting to find in the place where they were to be cached is fruitless. We also ransack the ranch house and corn crib with the same result, except that we find about three pounds of dried apples and half a pound of raisins. Galloway, who knows Emmett better than I, says, "I believe the old cuss has kept the money and purposely forgot the supplies." If so, it is very awkward, because we have but three or four pounds of flour, very little coffee, no baking powder, bacon, or anything else. In fact it is an aggravating situation. When I was planning this trip I wrote to Emmett who then lived here and whom I knew, sending him a check for fifty dollars, with the request that he have ready for us at the time of our probable arrival enough provisions, flour, bacon, one ham, coffee, baking powder, et cetera, for five men for ten days, also in case he should be away to cache the stuff, properly boxed, at the upstream side of the stone fort. This he wrote me he would do. Therefore, counting on those supplies, we have not been as saving or economical of food as we might have been otherwise. It would be impossible to go out to Kanab, ninety miles on foot, so there is nothing to do but go on to Bright Angel Creek as quickly as possible.

Mr. Ryder expects to leave for Kanab November 1st and offers to take any letters we wish to send, but as we expect to reach Grand Canyon as quickly as he reaches Kanab, we thank him for the courtesy of which we do not avail ourselves.

We take off skegs, fix oarlocks, raise the canvas shields around the cockpits a little higher, and generally overhaul the boats to make them as dependable as possible.

Thursday, October 28, 1909.

Sky full of light clouds except in the west where they are very dark and heavy; little wind. Four men drive in from Searchlight on their way to Wright's Bar, twenty-five miles or so up the river. We *might* get their team to go out for provisions, they having none to spare, but since we are nearly ready to start and have determined to go, there is no use to change the program. And so at 1:23 P.M., having had a light lunch, we start. Mr. Ryder and the four men are on the bank to see us run the first rapid which we do in a little over four minutes, and at its foot say good-bye to Ryder who has ridden along the bank at a gallop. Then we pass into Marble Canyon and after two very light ones we reach the head of Badger Creek Rapid at 3:40. Galloway sets traps while Dubendorff and I begin portaging part of the loads. Then the boats are lined and we make camp at the foot. This is a bad rapid from nearly every point of view, save that the portage is fairly easy. We see some old footprints, probably made by prospectors who came down the side canyon. Ryder said some had been in here but had found nothing.

The moonlight falling on the opposite wall, the shifting shadows, the deeper recesses which seem half elusive in the waning light, all blend into a truly glorious panorama. Here where the world seems shut out the spirit and spell of the wilderness still abides and welcomes one into the full freedom and magic of the "huge and thoughtful night," uplifting and swaying the beholder with a sense of being that is delightful past compare. At last I feel that my long-cherished hope of going through these great canyons is to have fulfillment, that I have reached the land where dreams come true.

Friday, October 29, 1909.

We start at 8:35, at 9:15 reaching Soap Creek, where we portage loads, line the boats about two hundred feet, and then load up and run the rest. While we are lining, the heavy current catches both Galloway's boat and my own with such force as to

jerk the bow line out of our hands. Fortunately, Dubendorff is able to hang on to the stern line in both instances until we can help him and so prevent either boat from getting away. This is a very bad rapid at the existing stage of water. The interference waves in its lower part are much higher than the waves immediately below the take-off, but they are not so broken up by rocks just beneath the surface. At a little higher stage of water we could have run it without difficulty. It was in an eddy just below here that Brown of the Brown-Stanton Expedition was drowned. We go on at 11:35, running four more. Then we stop for noon under a ledge on the left at 12:25. Through here the canyon is narrow and frequently boxed, the walls on both sides rising from the water so nearly vertical as to be unscalable.

Off at 1:20 and at 3:10 we come to a bad one caused by a narrow canyon coming in from the right. We portage half the loads and each runs his boats through, Galloway having got all over the trepidation he had in Lodore Canyon as to our being able to handle our own boats. Then we continue until 4:10 when we come to a small side gorge on the left and luckily see five goats on a ledge high above the river. At the third shot the smallest one comes tumbling down the terraced wall almost to our feet. This is fortunate, because had it not fallen it would have been impossible to climb up and get it. All prospect of short rations is now at an end, but alas! Our chance for *adventure* has also gone glimmering. One may only have an adventure if through oversight or lack of information inadequate preparation is made for whatever is to be undertaken. If he then meets with unforeseen difficulty, an adventure may result. Stefansson, who ought to know, says having an adventure is proof of incompetence.

As my side hurts pretty badly we make camp just below on the left. Galloway prepares another plaster, but I will use the hot water applications to-night, as I have heretofore. We have now passed fifteen rapids in this canyon. At this writing, 7:50 P.M., the wind is rising quite strong. Just below us in midstream is a very large rock, also one or two smaller ones which Galloway

says have fallen since he was here fourteen years ago, but he must be in error, because Dellenbaugh speaks of seeing them when he was here.

Saturday, October 30, 1909.

In spite of my diligent application of hot cloths my side is still quite painful. If it gets much worse I am afraid I shall be unable to handle my boat, which would create an awkward situation. It is now no better than last evening.

Off at 8:45 and at 9:25 we come to a severe rapid caused by a side canyon on the right. Here the loads are portaged about three hundred yards while Galloway and Dubendorff line the boats on the opposite side about one hundred feet and then run them across where we load up and run four more, one of which is very wild but free from rocks. We stop at 12 M. on a high bank on the left side where there is some grass.

During the entire forenoon there has been a violent wind up stream, sometimes so strong as to make headway against it difficult even with the aid of the current, and with the canvas fenders down. Off at 12:50 and soon we come to where the marble rises above the water. We run four rapids, the last one very turbulent and swift. Then we portage about one hundred and fifty feet at the next one (Number Twenty-five), line the boats, reload, and run the rest of it. Number Twenty-six is also rough but we run it without difficulty and camp on the right at the mouth of a side gorge just below a short bad one, at 4:50. We hope to run this in the morning after packing our stuff to the first eddy below.

The walls have now risen to a great height and are grand beyond description. What a pity it is that the spoken word cannot approach the visual eloquence of nature! Here it seems to outrun even the grasp of the imagination.

My side is still very sore. I may have to lay up for two or three days to nurse it with hot water applications. Here we find driftwood one hundred and seven feet above the present water level.

Sunday, October 31, 1909.

Galloway says that yesterday we ran four rapids that he and Richmond lined. The side gorge where we camped last night is short and boxed near the top. Here are many springs of clear though somewhat warm water. The marble has now risen one hundred feet or so above the water and is beautifully exposed on the left. My side feels better.

Start at 8:35, run the first one in good shape, then load up and go on. At 9:25 we reach a tough rapid caused by rocks from a side canyon on the left. We line the boats about two hundred feet, run the rest, and are away at 10 o'clock.

We have passed ten rapids this forenoon, not counting the small ones, one being S-shaped and quite long, with a small gravel bar in the middle. Opposite this a number of copious springs gush out of the rock at various heights on the right, and, clothing the otherwise naked wall in exquisite beauty, the loveliest green drapery hangs in graceful festoons. No artificial arrangement could outdo this wonderful hanging garden that Powell named Vasey's Paradise, and no more appropriate designation could have been found. In this environment it is as enchanting as the liquid melody of a song bird in an otherwise silent wilderness.

We are off once more at 12:50 and run everything this afternoon, including two or three very lively ones. We have passed through twenty-one to-day, making a total of forty-six so far in Marble Canyon. We camp at 4:25 on the right on a flood plain of sand overlying a bed of heavy rocks causing a small rapid just below. Here are mesquite, small willows, and hackberry trees, also some cat-claw and tall, coarse grass. We must be somewhere near the mouth of the Little Colorado. If so, we may reach Bright Angel the day after to-morrow night, which would put us almost a month ahead of our original schedule. My side feels somewhat better, but on suspicion, I will again use hot water applications. This involves no difficulty other than keeping a fire all night and prevents me from getting much sleep. I am now pretty well "tuckered out," notwithstand-

ing my otherwise splendid physical condition. Unhampered by this slight attack now apparently passing away, I can easily outdo the others, but sleep is becoming an insistent necessity.

Monday, November 1, 1909.

Under way at 8 A.M. and soon pass several small rapids. At 9:20 we come to a rather bad one which, after examination, we run without incident. This is followed by a somewhat less violent one and that again by others, all of which we run until 10:50, when we reach the Little Colorado.

The water it brings in is limpid but salty from salt springs a few miles up stream. Its bluish-white color contrasts strangely with the muddy Colorado. Luckily, our fears that this stream might bring in a flood are groundless. After taking three or four pictures we go on at 11 o'clock and run to the big dike, where we stop for lunch on the right side at 12:05. Someone has driven a prospect hole into the ledge at this point, and we naturally inspect it. The result of this investigation is a net increment to our larder of two cans of milk, two of beans, two of salmon, and one of syrup, for which we give silent thanks to the owner, whoever he may be. We need the provisions, but take only enough to help us out. We hope he will still strike it rich and be rewarded a million-fold for his involuntary generosity! I wonder if this is the way every burglar feels?

At 3:15 we come to a long bad rapid along a vertical wall on the left. And as it looks equally bad on the right side, Galloway crosses to examine the other side. On his return the boats are lined on the right for three hundred and fifty feet or so with the loads in. Then we run the rest and reach the head of the upper granite in the Grand Canyon at 4:10, where we make camp on the left. We have to-day run eighteen rapids in the Marble and thirteen in the Grand Canyon, or thirty-one in all.

Tuesday, November 2, 1909.

We start at 8:05. At 9:35 we reach a long, rocky rapid where the loads are portaged about three hundred yards while

Galloway brings the light boats through. It is a difficult one at the present stage of water because the channel is filled with rocks, but we finish at 11:20 and go on until noon, then take a snack on the left bank at 12. We are off again at 12:50, running a succession of rapids until we come to the much-touted "Sockdolager." It is possibly one-third of a mile long and boxed from the beginning. We climb a ledge on the left as high as we can to examine it, pick out a channel, and then start. It is a rough piece of water, sure enough, but luckily everyone comes through with little more than a soaking and a lively sense of having been tossed around considerably. We take five snapshots from the boat while we are running it. These photographs show turbulent waves but none approaching thirty feet in height. We land on a ledge at its lower end and Coggswell levels it to ascertain its declivity, there being some discrepancies in the estimates of various writers. This comes out as being thirty-four feet and some inches.[1]

We soon come to another considerably shorter one. This is also run without incident other than quick, hard work. Again below this is a very short one having a fall of possibly ten feet in fifty. As a result the waves are unusually high, probably eight feet (possibly two or three are ten), but this is also run without incident. Then there are a number of others making twenty-two in all to-day, only four of them really bad. We reach the foot of Bright Angel Creek trail and go into camp at 4:20 on the north side, near the "tramway" (a cable across the river). Then we hunt for Dave Rust, whom we expected to find here. But all seems deserted, so we will start up the trail early to-morrow, to take out the exposed films and to bring back unexposed ones, as well as provisions for the rest of the journey.

Wednesday, November 3, 1909.

We start up the trail at 8.20, I with a pack of exposed films, et cetera, Galloway with another, and Cogswell with a camera,

[1] An accurate survey since made by Colonel Birdseye proves everyone to have been in error, the declivity being between twenty-four and twenty-five feet.

leaving Dubendorff to look after the boats. We get to the Indian Gardens for lunch and to El Tovar at 3:40, staying there over night.

I wire home and get a reply saying our little son, two years old, has had congestion of the lungs. I telegraph Mrs. Stone to start for California as soon as Franz can travel, taking all the children and a nurse, saying that I will come to Pasadena from Needles unless he is dangerously sick, in which case I will come home at once. No reply to this has arrived up to bedtime.

Before retiring I pack up the films that are to be shipped home and unpack those we are to take with us to-morrow. The package I carried up from the river weighed twenty-nine pounds. Galloway carried twenty-three pounds.

We might have gone on to the foot of Bright Angel Trail instead of starting up the rougher, steeper, and longer one from the Tramway, but thought we were at Bright Angel, whereas in fact we were farther up stream, though we did not find this out until to-day on reaching the rim. "Learn one new thing each day" is the old maxim. In this instance we heeded it, but at the cost of some weary miles that we might have avoided had we known just where we were.

Thursday, November 4, 1909.

At breakfast I meet a Mr. Weaver, from Columbus. I also receive telegraphic advice that Mrs. Stone will start for California as soon as possible. Therefore, we decide to finish the trip and wire home to that effect.

Arrangements are made with a Mr. Fleming, who has charge of transportation at El Tovar, to bring our supplies down on a pack animal *early* in the morning. Then we get our lunch and start down the trail at 1:30, reaching the river at 5:35, where we have to wait a little while before Dubendorff shows up and brings a boat over.

Galloway objects to resuming our journey to-morrow because it will be Friday, but he has too much good sense about

other things to harbor such a fool notion, and is old enough to learn that it is nothing else. Therefore, we will start as planned.

Friday, November 5, 1909.

We take to the river again at 8 A.M. and drop down to the foot of Bright Angel Trail, where we await the packer with our supplies. He and Mr. Fleming come promptly at 8:25 and we are on our way at 8:50. We reach Horn Creek rapid at 9:25, where the loads are portaged a short distance. The boats are then lined part way, then taken out thirty feet and lined to the foot. We reload and start at 12:25, stopping for lunch about a mile below. At 1:30 we are off again and at 2:15 come to Granite Falls, a very heavy rapid full of large rocks, the water dashing against a vertical wall on the right. We *might* run this, but decide to portage and line part way, a process which takes until 4:20. We make camp at the foot on the left. The sky being full of cloud-play, we are treated to a gorgeous sunset. Red, blue, purple, and flaming gold are flung in riotous profusion across the open space above us, swinging and shifting in combinations and recombinations of the keynotes of yellow, red, and blue. Surely no audible melody is more entrancing or inspiring than this visual music of the skies. The sweep of its harmonious variations transcends description. It lies beyond the potency of words. Here with the impassive, dead gray of the naked granite about us, with the unquiet and inhospitable river at our feet, the glory of the scene above us unfolds in never-to-be-forgotten splendor.

Saturday, November 6, 1909.

Starting at 8:05, we reach the Hermit Creek rapid at 8:25. This is a bad one. We portage everything, line the boats part way, take them out and around a large rock, line to where the loads are, then run the rest, and are away at 11:40. Galloway, Dubendorff, and I all get bunged up by slipping on the wet rocks while working here. Dubendorff narrowly escapes being killed by falling on his head among the boulders. He welcomes every

experience with a laugh and eagerly comes back for more. Nature surely wrapped his skin around a real man. With no boating experience prior to our start he has become masterfully competent to do whatever is necessary. At 12:10 we stop on the left. Resuming the voyage at 1:10, we soon come to another heavy rapid which we might run were it not so full of rocks. So we drop part way down and unload. Galloway takes the boats through light while we portage the loads. We are away once more at 2:20, running everything until 4:10, when we reach another one which might be safely run but for a bad rock in the middle of the channel toward the lower end where it narrows and the entire current sweeps against, or rather toward, the rock. We decide to portage on the right side, make camp, and line the boats in the morning. This portage, though only about one hundred and fifty or two hundred yards, is a tough one, being over and among very large rocks.

A strong wind has blown up stream for two hours this afternoon. We passed eleven rapids yesterday and ten to-day, not counting the small ones, though there have been few that could be called really small. The river is high for this season of the year and the rapids correspondingly accentuated. The top of the granite is much lower to-day, but will rise again when the river turns south.

We shall be glad to be out of it. The gray monotony of its naked walls is anything but enjoyable or interesting, excepting to note the large number of fissure veins, some of which are truly enormous, but all probably barren of metal save to a small extent.

Sunday, November 7, 1909.

Starting at 7:50, we are through the rapid just below by 9:25. Running the next five, at 10:50 we reach a heavy one caused by a side gorge coming in from the left. Here we line part way on that side, then unload, and portage about one hundred and fifty yards, take the boats out thirty feet, line down to the loads, get our lunch, and are off once more at 1:25.

At 2 P.M. we come to Bass's Trail. Here on the right we

find a note held in the split end of a stick stuck into the mud at the water's edge stating where we will find a letter, which I get. It is from W. H. Sharp, a brother of the Sharp of our party. He tells us to be sure to see Mr. Bass, as "he knows more about the whole river than *anyone*." Sorry not to have time to do so, we proceed and at once come to a stretch of swift water. The rapids are frequent and the average declivity of the stream seems as great as anywhere thus far. At 3 P.M. we reach an especially bad one where a gorge comes in from both sides and a ledge juts out into the stream from the left about one third of the way down the rapid. There is at this stage of the river no chance to run it, as it is very heavy and full of rocks. One with a sharp edge in mid-stream causes two sprays of water to rise three or four feet into the air like a pair of perfectly curved horns.

We line the boats part way down, one at a time, on the left, then unload, line farther, and take them out about two boat lengths, then line to an eddy below two ledges of granite, Dubendorff's boat first, then mine. By this time it is too dark to do more, so we camp and dry ourselves by a big fire, there being plenty of driftwood. We are now near Powell's Plateau and at rapid Number 138 from Lee's Ferry, according to our count, which is fewer than Stanton's, and Number Seventy-four in the Grand Canyon. This is probably the most difficult rapid we have had to contend with, doubtless because of the existing stage of water.

Monday, November 8, 1909.

We begin on Galloway's boat at 7:30 and are all finished, loaded up, and off at 8:35, running everything until 12:05, when we stop for lunch on the left, having made good progress this forenoon. The grade of the river continues steep. The granite disappeared at 10:40.

At nearly every camp and at our noon stop to-day we have seen otter sign, usually quite fresh, but we catch no glimpse of even one. Here, as we land, are seen the tracks of two from

the water to the rocks that must have been made but a few moments ago, because the sand is still wet with the drippings from their fur. Galloway is so absorbed in his quest for them that he eats no lunch. The spirit of the chase is certainly a part of his being. With no especial effort he notes the slightest indication of all kinds of wild life and, knowing their habits so thoroughly, readily discerns what they will do. However, he fails to run the two otter out of their hiding place. Hunger, discomfort, hard exertion, and everything the average person shuns have no existence for him when the quarry is near. Man is of necessity a stealth hunter. Galloway seems to possess all the resourcefulness of early man who lived by the chase alone. I have seen him go through a heavy stand of dead willows almost as noiselessly as the proverbial shadow, while I trying to follow him made comparatively as much racket as a stampeding drove of hogs.

We go on at 1:05, still running everything without mishap, until 3:15 when we arrive at a rather bad rapid. Here, as in several previous instances we do not agree among ourselves as to the best method of running it. Galloway picks his course along the right where there are quite a number of rocks but no big waves. I incline to the open water, even though it is rough, while Dubie, coming last, avails himself of the route taken by the one who gets through more easily.

Galloway goes ahead, I next, and dropping into an eddy below the first rock I see he has been unable to follow the course he picked out. His boat strikes a partly submerged rock twenty feet from the place he tried to reach. This confirms my decision that the heavy water is safer. For me, it turns out to be correct, as I go through all o.k., getting wet, of course. However, on looking around at the first opportunity to do so safely, I see Dubie's boat on the crest of a big wave near the upper end of the rapid. Then it goes out of sight, reappears in the act of turning over almost endwise, and comes down bottom up. Now and then I glimpse his head bobbing up a moment, then disappearing again, but out of sight the greater part of

the time. I call to Galloway and try to catch the bow line of Dubendorff's boat as it reaches me, but am unable to do so because of the high canvas sides on my own, I not having had time to drop them. Galloway slips his line through the iron handhold at its stern, takes a hitch around his leg and so tows it to the right bank before it reaches the next rapid. I pick up the other things as they float down, then Galloway and I strip off, go into the water, turn the boat right side up, pull it up on the rocks, and tip the water out.

In the meantime Dubendorff, who so suddenly decided to run this one without a boat, and succeeded, has crawled out about three hundred yards below where the spill occurred. He comes down to help us. His head is pretty badly cut and with the blood streaming down over his face he surely looks unhandsome. Still, his first words are, "I'd like to try that again. I *know* I can run it!" He is as gritty as a flapjack rolled in sand. But all's well that ends well, for we soon cross to the left bank, build a fire in a sheltered spot (wood is a little scarce) and warm ourselves. I tinker up the cut in Dubie's head. The wet stuff is spread out on the rocks to dry and, but for a broken oar, there soon is small evidence of trouble.

It seems that when Dubendorff's boat went over the first big wave, the end of the extra oar, lashed on the deck behind the cockpit and projecting over the stern, caught on a rock. The speed and inertia of the boat were such that it went over endwise. This is the last rapid in "Conquistador Aisle," so named in the Shinumo quadrangle of the government map. Whoever runs it successfully at a corresponding stage of water will know the satisfaction of having accomplished a man's job. Twenty rapids to-day with no trouble except as noted.

Tuesday, November 9, 1909.

Starting at 8:10, we run everything to Kanab Wash, which we reach at 11:25. Inspecting the rapid just below, we decide to run it (Hobson's Choice, there being nothing else to do!). This is done with little difficulty. Then we stop for lunch at

11:50 on the right at its foot. Dubie accidentally drops one of our skillets into the river as he is taking part of the camp kit out of his boat. This leaves us but one, so I strip off and, with a rope tied around me, the current being swift, hunt among the rocks until the water gets too chilly, but fail to recover it.

Off at 12:40. At 2:15 we see a band of bighorn on a ledge to the left. This is the third lot we have seen to-day. Being short of meat, we stop and go after one, the net result being that we bag two, a young one and a magnificent ram, its horns measuring seventeen inches in circumference at their base. There were five rams in this bunch, and as I went to skin the big one the others walked somewhat leisurely away. A number of others went up a broken-down place in the wall to the next bench above. These animals were so tame that it seems fair to infer they had not seen human beings before. We might have killed all of them but I am glad no one even suggested shooting any more. This now makes it possible to supply the Ohio State Museum with as fine a pair of *Ovis montana* as I have ever seen.

It takes me until 4:10 to skin out the ram. In the meantime Galloway and Dubendorff have skinned and cut up the lamb. Then we climb down—more difficult than coming up—and hunt a camping place, which is found under an overhanging ledge on the left, so to-night we will sleep under a roof possibly a thousand feet in thickness. We find only one large piece of driftwood. This is on the opposite side and it requires some effort to cut it in two and bring it across piecemeal.

It is storming on the rim. The wind up stream has been very violent this afternoon. A few splashes of rain and even some snowflakes have reached the river.

We passed a beautiful waterfall, possibly one hundred feet high, above Kanab Wash. It comes in from Surprise Valley on the north, there being also many crevices in the wall from which water is flowing. Vegetation has made the most of this opportunity, the result being a vertical flower garden of rare beauty.

We are now below rapid Number 107 in the Grand Canyon.

After supper Galloway and I fix a bread skillet by riveting a piece of tin to the rim of an extra plate. We then flesh and salt the bighorn skin and call it a day.

The water brought in by Kanab Wash is not heavy in volume, but is very dirty and a marked yellowish-red in color. All the bighorn we saw to-day were on the south side.

Wednesday, November 10, 1909.

Off at 8:05, running all rapids without incident until noon. The river is swift, the walls very high and generally boxed. At 10:40 we reach the mouth of Cataract Creek. Its contribution of water is small but limpid. At 12:05 we stop for lunch on the right, and are off at 1 o'clock, facing a strong head wind. At 3:15 we come to Lava Falls. Here we portage the loads and line the boats down to where they will have to be taken out in the morning and then make camp on the left on a ledge of calcareous material deposited by warm springs.

Powell describes these springs as being "one or two hundred feet above the river." Possibly they were at that time, but at the present they are not more than twenty feet above the water, and we see no evidence of their having been higher in the past.

Shortly after starting from our noon stop we see a mountain sheep on the left side. The graceful animal follows us a mile or possibly more, running along the ledges and talus with the greatest ease, even down a seemingly vertical wall probably thirty feet or more in height. Its airy nimbleness more nearly resembles flight than locomotion. But finally it drops back and stands watching us until lost to view. At another point a large ram looks down at us from the brink of a precipice rising directly from the river, its head and shoulders beautifully silhouetted against the sky. It would make a wonderful picture, but Coggswell is not ready with the camera, although it remains there statue-like for at least a minute after his attention is called to it.

Here in recent geologic times has been a great lava flow from

the northward into the canyon which filled the inner gorge to a height of possibly one thousand feet. At least the buttes and walls are all discolored to a great height above the river, but the patient, persistent stream has taken it nearly all away.

Thursday, November 11, 1909.

It is very cold after midnight. We start portaging the boats at 8:10, are loaded up and off at 9, after which we run everything until noon. At 12:10 we stop for lunch on the right side. At 11 o'clock the granite came up again but only for a little way. We have passed many remnants of lava this forenoon, including old flows from the north rim to the river, and now hope to reach Diamond Creek in three days. If we do, practically all our troubles will be ended, that being the last very bad rapid in the canyon, so Galloway says. We are off again at 1:05 and at 3:50 stop on the left bank for the purpose of drying the sheep skin before sunset, also to have one good comfortable camp before tackling the lower granite which we should reach to-morrow. We have without difficulty run every rapid this side of Lava Falls.

The last one to-day was lively, making eighteen in all, a total of 204 from Lee's Ferry, and 140 in the Grand Canyon.

Friday, November 12, 1909.

There is a brisk, cold wind down the canyon which feels like snow, or rather indicates a storm, probably with snow, in the upper country. It rained a little during the night, and at times the wind was high. We are off at 8:05. At 10:35 we come to the lower granite. We run all the rapids until 11:45, and then stop on the left for lunch. Off again at 12:45 running everything until 4 P.M., when we make camp on the left below No. 174.

In rapid No. 172 one of Dubendorff's oarlocks pulled out of its socket, he not having them properly wired in. He narrowly escaped being wrecked on a sharp rock on the right. As

a matter of precaution we stopped at once and secured them properly.

We have to-day run thirty-four rapids, all of more than average severity, some of them very wild, but except for Dubendorff's little mishap have not made a blunder of any sort. We now feel confident that we can run any rapid through which it is possible to take a boat and live. The air feels shivery and snowlike. There doubtless is or has been a heavy storm on the rim, but that is far above us. We saw butterflies during the midday hours. Still, we have seen one or more nearly every day. On the left side this afternoon we passed a large deposit of travertine, covering the granite like a great curtain. Here also we saw a beautiful rill trickling down the wall from its top, leaving a marked deposit on the face of the cliff, a sort of vertical flood plain.

Saturday, November 13, 1909.

Glorious sunrise, no wind. Off at 8 o'clock and run everything down to Separation Rapid, where three of Powell's men went out on the north, and were afterward killed by the Indians (see page 98 Powell's monograph, "The Colorado River of the West"). We reach here at 9:15 and examine it carefully, taking photographs from all advantageous positions in order to show the situation clearly and supply Stanton with such copies as he may wish to use in his book, he having some interesting information with regard to what occurred in Powell's party at this point. He, Powell, states they could not see the three who were left behind from the first place at which it was possible to stop after starting down the rapid.

Here there are really three rapids in succession, *all in a straight line*. Then there is a fourth one partially around a bend where a large slanting rock lies at the water's edge on the right. The upper rapid is heavy but nothing at all like Powell's description, though after having run it, he states it was not nearly as bad as he had expected. The second is less wild and the third hardly more than a bad riffle. There are several eddies where a boat or boats might stop without difficulty on either

side below each of the three rapids. We did so and there can be no doubt of it. Powell says they had to pull with all their might to keep their boats off the slanting rock in the fourth rapid. I purposely let my boat drift on approaching it and did not come within ten feet of it.

At 11:45 we come to what Galloway says is Diamond Creek, where we lunch on the south side above its mouth.[1] It is a beautifully limpid little stream, but the rapid its contribution of rocks causes is a terror. If fear has any message for us or disaster any threat, here is where we should hear it on the quivering air. The shock of the angry water actually makes the air pulsate. Looked at from every viewpoint this is, as Galloway says, the worst rapid in the whole series of canyons. We cross to the north side at 12:30 and begin portaging all our loads over the saddle of a lava-capped cliff. It is one hundred and fifty feet or more in height. The eastern slope is of loose broken rock lying at the angle of repose, but apparently willing to be disturbed by the slightest shock. To make matters worse, there are quite a number of cacti and small cat-claw bushes among the debris. The western slope is steep and bare. Toward evening all has been carried over and along a shelf five or six feet above the water to a point four hundred feet down stream. At dark the boats have been let down just below the first plunge and from here we shall have to take them out for thirty or forty feet in the morning, then line them to where the stuff is. We make the boats as secure as possible in an eddy, but after dark find the current is tossing them so badly that we pull them up on the rocks as far above the water as space permits.

The wind is from the north and very gusty. The sky is cloudy, and as it threatens a storm we pitch our tents on the bare rock, shoveling in some sand to take the curse off. Then with the little driftwood gathered before dark we make supper and turn in, tired out but d——d thankful we are here.

[1] It turns out that we were at Diamond Creek on the 11th and that this is an unnamed creek, probably twenty miles below.

This forenoon, just after arriving, while clambering over the rocks on the left side in order to look the situation over as thoroughly as possible, I slip and as I fall the heel of my right shoe wedges between two rocks in such a manner as to leave me hanging head downward with my back toward the rocks and wholly helpless. Galloway and Dubendorff quickly get me loose but my ankle is badly sprained. Dubie's knee, hurt at his last spill, is now swollen and painful, so he and I have not had a very pleasant day's work.

This rapid being wholly boxed in at its head, the face of the ledge on the right rising vertically from the water, it is very difficult to line. We are fortunate, however, in having an extra rope which we stretch along the cliff face to keep us from tumbling into the river. At higher water it might be run, but even then it would be bad. At the present stage it would be inviting disaster to attempt it.

We are now pretty well practiced in handling our boats through rough, swift, and difficult places, but do not feel like going out of our way to take a chance of bidding the Devil good-morning.

At 7:35 P.M. the wind has quieted down. To-day we ran everything down to this one, 190 so far in Grand Canyon, passing one place this afternoon where the river at this stage of water was not over thirty-five feet wide, being boxed in and correspondingly swift. A rise of three or four feet would spread it out to two hundred and fifty or more.

Last night Galloway shaved and washed himself carefully. He has done this at three or four bad places, but not elsewhere. Dubendorff and I are wondering whether it is not due to some little superstition, but as we probably have other kinks that seem equally queer to him, we call it a stand-off.

Remnants of lava are found all along the river from Lava Falls to this point. We have now passed 222 rapids in the Grand Canyon and 64 in Marble Canyon, making 286 below Lee's Ferry.

Sunday, November 14, 1909.

It is very cloudy and threatening a storm. Southwest wind. It sprinkled a few times during the night. We hope to reach the end of the granite to-day. I did not sleep at all well but am feeling bully this morning. We begin work at 7:30 and in one hour have taken our boats down to where we camped, loaded up and are off, running the rest of this rapid. Then we run everything until at 12:15 we come to the end of the granite. We stop on the right, put on skegs for the last time, eat a bite, and are on our way at 2:10. Very cloudy. There is a high, gusty wind. The air is full of sand particles which are blown about like dry snow but are much more annoying, especially at lunch. At 3:10, a storm being almost upon us, we stop at the first available place on the left. Hardly are the tents up when it begins raining heavily, dense black clouds rolling into the inner gorge until the cliffs are hidden behind their misty veil. It becomes very dark, but now and then through a cloudrift we can see the snow falling on the rim, though the precipitation reaches us mostly as a chilly rain. Intermittently we hear the distant or nearby crash of rock masses falling in the side gorges around us. Fortunately, our camp is in the open and we are wholly out of harm's way. Still, these reports, like the sound of distant guns, the whistle of the wind, and the swish of the driven rain and sleet make us appreciate the security of our position very keenly. The rolling storm with its gathering gloom about and above us, composes and completes an elemental panorama in as grand a setting as few have ever had the privilege of beholding. I am glad this glory has fallen to our lot once, but once is just enough. It continues until 4:30 A.M. and brings us much physical discomfort.

To-day we ran thirty-two rapids, but without serious trouble. In one short, swift one we again felt against our faces the rush of air due wholly to our velocity. There have been probably half a dozen marked instances of this kind.

This afternoon the right wall was curtained by a deposit of travertine for a distance of two and one half or three miles.

The distance from here to Needles cannot be more than two hundred miles. This we should accomplish in six or seven days, if we have good weather.

Monday, November 15, 1909.

No wind, no clouds, no hint of the unquiet night except for the frosty look and feel of everything. The whole scene is so changed it hardly seems like the same environment. A few hours ago all was darkness and blustering storm. Now there is the still, clear air of the morning, the white benediction of the snow on the crags above, and the ineffable blue of the sky beyond. Under this enchantment, he must be dull indeed who does not in some degree feel the uplifting stir of emotions that are new and strong and fine.

We start at 8:45. At ten o'clock we run out of the canyon, and my hope of many years has become a memory.

The strenuous effort, the chance of failure, and the eager stimulation a difficult task inspires—all are ended. And yet, strange to say I feel no sense of elation. Possibly it is because the hurrying years are leaving more and more of my life behind, and *this,* to which I have eagerly looked forward so long, has now passed into the shadows that fall and lengthen toward the east.

At 11:50 we stop on the right just below the mouth of Grand Wash. We see five wolves and several bobcats below the end of the canyon. I stop and try to get a bobcat, but it disappears among the rocks before I can get a shot. Then we come to Pierce's Ferry, which has been abandoned.

Off again at 12:45 and at 4:05 we reach some placer diggings where we find a Mr. Cox, who kindly supplies us with sugar and baking powder. He and some others have been here a long time but find the gravel not worth working. Now all the rest have gone and he is going soon. After a visit of twenty-five minutes we go on, camping about four miles below on the left at 5:30. We have passed nine light rapids, that is, light as compared with those in the Grand Canyon, also several lesser

ones. We will start early to-morrow in order to reach the Virgin River by mid-afternoon. I try to get another wildcat, but fail.

Tuesday, November 16, 1909.

Up at 5:40. Heavy white frost. Off at 7:35, reaching the Virgin River at 12:05 and lunch on the left. Bonelli's ferry above the mouth of the Virgin River has also been abandoned. No one is now living in the house once occupied by those who attended the crossing.

Powell went out at this point, ending his first trip (the second expedition terminated at Kanab Wash), Sumner and Hall going on to the Gulf.

Off at 1:00 and at 5:10 we emerge from Boulder Canyon. A little below its mouth we come to the ruins of "Old Callville," where in 1867 James White was taken from a raft after having, *as he claimed,* passed (on that precarious platform!) through all the canyons from a point somewhere above the junction of the Green and the Colorado in thirteen days—a claim so manifestly incredible as not to win the belief of anyone who has passed through either the Marble or the Grand Canyon.

A mile or so below Old Callville we see three Indians or Mexicans in a boat. They act in such a way as to excite our suspicions a little, and Galloway thinks we had better go somewhat farther. This we do, not making camp until after sundown, on the right, just below the foot of an island and above the mouth of Las Vegas Wash, in the State of Nevada.

Here are very many beaver sign. We hear several beaver around our boats after dark.

Wednesday, November 17, 1909.

Galloway caught two beaver, one medium and one very large. The big one must weigh seventy pounds. Here they are very numerous. All through the night, whenever we were conscious, we could hear the slap of their tails on the water, indicating they were much disturbed at our presence.

We make a rather late start at 9 A.M., but soon run into Black Canyon and at 12 we stop for lunch on the right side. Here we see a honey bee, probably from some colony that has strayed and found a home in the rocks.

Off at 1:05 and at 2:10 we reach the mouth of Black Canyon, and then come to Eldorado at 3:05, where we stop forty minutes. Here, luckily, we are able to buy four cans of fruit, a ham, two dozen eggs, and a pound of butter from a Mr. Weiss, who is custodian of a mining property which is now idle and practically abandoned.

His housekeeper, Mrs. Atwell, tells us that the four California placer mining men whom we saw at Lee's Ferry stopped here on their way back to Searchlight, staying several days, and that they told of having seen us start, but that we were surely lost, as they had seen pieces of our wrecked boats floating past since coming here. So much for that!

We go on until 5:10, stopping on the left side in as fine a camping place as we have found anywhere. Ham and eggs, hot bread and butter, fruit and tea for dinner! Surely, this is roughing it!

A couple of miles above camp we passed a gold dredge at work in midstream. We learn at Eldorado that they are not doing well, either.

Thursday, November 18, 1909.

Up at 5:40, have a fine breakfast, and are off at 7:35. The water is comfortably swift. A strong down stream wind soon springs up and helps us considerably.

At the first rapid in Black Canyon yesterday I carelessly omitted to turn my boat (stern down stream) and looking over my shoulder failed to see the sharp top of an almost submerged rock until too late to avoid it. The right corner of the boat struck it about five feet back of the bow, causing a slight leak. This rock and the one on which I was hung up in Red Canyon are the only two I failed to miss in the entire distance. The one in Red Canyon did not damage the boat at all. Gallo-

way's record is even better, his boat having struck but one and that in the rapid where Dubie was wrecked the last time.

At 11:50 we stop for lunch on the west side on a long bar from which a strong north wind is raising clouds of sand, making it very uncomfortable. Were it any worse we should have to stop altogether and cover up. Here we see an enormous flock of snow geese at a great height, probably several thousand, going south. The strong wind prevents them from flying in their customary formation and whirls them about in the utmost confusion. Their incessant squawking indicates they are greatly excited about something. Their plumage, pure white excepting the wing tips, which are black, gives the swirling mass the appearance of eddying snowflakes.

Off at 12:45. The river is rising. We come to a recent flood plain which the current is cutting away with astonishing rapidity. The water being deeper and swifter on the outside of the bends, we naturally follow the volume of the current. This takes us along the caving edges of the plain which rise probably ten feet above the river. One large mass is dislodged just as Galloway is alongside of it and almost submerges him and his boat. Had he been closer, it would have buried both at once, and it is very doubtful if he could have got out. After this, we stay far enough away from the higher banks to be reasonably safe.

We reach Fort Mojave at 3, where we stop at the Power House, wishing to pay our respects to the officer in charge, it now being a government Indian School, and in the hope that he will invite us to supper, possibly to stay over night. But on inquiring for him, we are told by the Indian in charge of the Power House that the school is quarantined because of smallpox. At once the river looks mighty good to us, and we go on at 3:10, making camp a couple of miles below, in the State of California. We might reach Needles to-night, but we wish to slick up some and generally make ourselves presentable. Then, too, Galloway wants to pack his skins for shipment.

We have had a heavy north wind all day, a circumstance

which has helped us greatly. Twelve years ago Galloway and Richmond made the distance from Old Callville to Needles in two days, twenty-five and one-half hours actual rowing time, bringing down the bodies of two men who had been murdered by an Indian, who was afterward caught and executed. Galloway has often said he thought no one could duplicate their feat, he and Richmond having received a special inducement to do their best. However, we have come from Old Callville here in a little over fourteen hours and should reach Needles in not over three more. Still, the wind has helped us. We also have better boats and are equally as strong. Therefore, we should make better time than they.

This is our last camp! In all probability I shall never be on the river again. This realization brings just a tinge of regret, though why is hard to say, since I would not care to try it again, nor to repeat any previous experience. Possibly it is because, and *only* because, this is *the end.*

Often and long I shall recall the incomparable exhilaration that came just as I felt my boat slide into the troubled waters of the wilder rapids, only to vanish with the breakers at the foot. All other outdoor experience that I have ever known is feeble and flat in comparison.

Friday, November 19, 1909.

We leave our last camp at 7:30. The air is very chilly. A heavy fog over the water makes it difficult to see where we should go. We lose sight of one another frequently, but in an hour the fog vanishes. At 10 o'clock we reach Needles and pull our boats out of the water.

Our journey is completed!

PART III

PHOTOGRAPHS AND EXPLANATORY TEXT

Where no descriptive text accompanies the plates, these illustrations are included only because they show characteristic and interesting canyon walls.

PLATE 1A

THE START

The upper photograph on Plate 1 shows river, flood plain, and bluffs at the town of Green River, Wyoming. The flood plain or lowland at the side of the stream passes by a low transition slope into the steep face of the buttes at the right. To the left in the photograph is the town of Green River, and to the right the buttes overlooking the town. The largest of these buttes, known as Castle Rock, rises six hundred and forty-three feet above the town. The buttes are composed chiefly of finely laminated shale known to geologists as the Green River formation.

This is classic ground in the story of American exploration. Here the Union Pacific Railroad crosses Green River and here were unloaded the boats and supplies of the first party that explored the canyons of the Green and the Colorado rivers. From this point the party under the leadership of Major J. W. Powell started May 24, 1869, on the memorable trip which resulted in the exploration of the Grand Canyon. From this same point several other parties have started, including the one which secured this group of photographs.

PLATE 1B

BLUFFS ON GREEN RIVER

From Green River bluffs are carved a great number of buttes and natural monuments of curious and picturesque form. The rocks of the lower parts of these bluffs consist of thinly laminated shale, chiefly of light green color, although many other colors are seen in one place or another. The beds higher in the bluffs have a brownish cast, and, because they are harder than those below, form the protecting caps of buttes and pinnacles. In Fish Cut, on the Union

Pacific Railroad three miles west of the town of Green River, many fossil fishes have been collected from this shale.

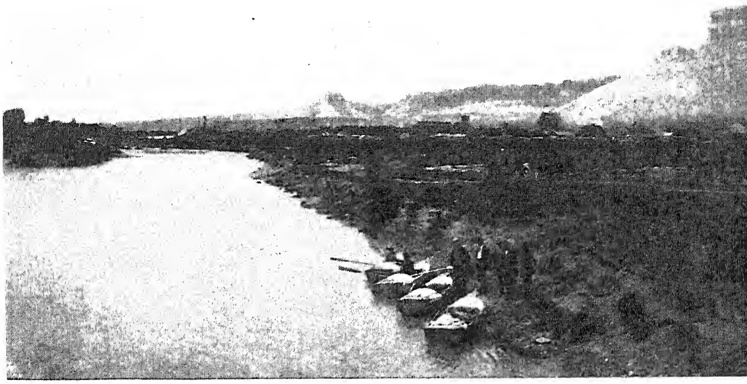
The Green River shale is the so-called "Oil shale" which may be valuable in the future as a source of petroleum. Certain layers in it contain carbonaceous material in the form of minute fossil plants, and when heated yield petroleum and ammonia. Some of the rock from the Green River beds has yielded oil in the proportion of thirty-one gallons to a ton of rock, and an amount of ammonia equivalent to thirty-four pounds of ammonium sulphate. The upper hard brownish beds differ from the underlying oil shale in being coarse-grained, cross-bedded, and irregular in appearance and composition. They lie in hollows of the shale because they originated as the filling of ancient stream channels. On account of their character they have been referred to as the channel sandstones, and because they now form the protecting caps of the tower-like buttes shown in this illustration they are known collectively as the Tower sandstone. They are believed to be outlying remnants of rocks in the noted Bridger beds, where many fossil bones of extinct animals have been found.

PLATE 2A

Beds of Banded Shale

Green River has eroded a broad deep valley in the Green River beds to depths of many hundreds of feet. In some places along the river flood plains have developed. In other places the walls rise sheer from the water's edge. The even banding of the rocks is beautifully exhibited where the exposed faces of the cliffs are free from growing plants. In this photograph the Tower sandstone stands out boldly against the sky line, resting on evenly laminated material made up of thin layers of shale in which is included a subordinate amount of sandstone and limestone. The remarkable regularity of the bedding has given rise to much speculation as to the manner in which the deposits originated. Though many problems connected with this peculiar formation remain unsolved, it is probably safe to conclude

Plate I



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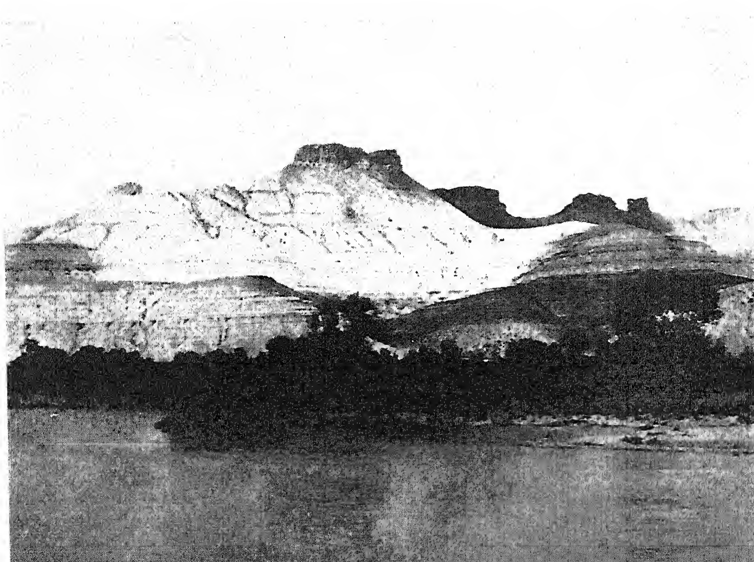

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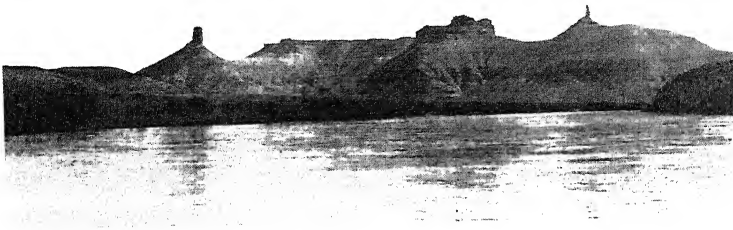
PLATE 2



A

B

that they represent the accumulation of mud and fine silt in quiet, shallow water.

PLATE 2B

AN UNDERCUT CLIFF

Where the river in swinging laterally, after the manner of streams, has undercut its rocky bank, some of the resistant layers have been left jutting out over the water. Here Mrs. Cliff Swallow finds protection in her adobe house. In the distance, rocks similar to those of the cliffs show a rounded surface characteristic of erosion by weathering. The rounded hills and hollows of such a surface contrast sharply with the results of the relatively rapid erosion by stream abrasion which produced the cliffs. At such an overhanging cliff, Major Powell halted on May 24th, 1869, and noted the strangely carved rocks of the Green River "badlands" where the sandstones and shales, gray and buff, red and brown, blue and black strata in many alternations are worn by rain and stream into fantastic carvings, imitating architectural forms and suggesting rude but weird statuary.

PLATE 3A

ISLAND AND SHOAL

Although Green River is a swiftly flowing stream having an average gradient or slope in this part of its course of about three and one-third feet to the mile and a velocity of three miles or more an hour, it carries a large amount of sand and silt. Much of this rests in the channel during times of low water but is moved during times of high water. If this material is heaped up under water it may take the form of a shoal or a bar; if its surface is slightly above water level it may have one of several well-known forms such as a spit, a hook, or a sand flat like the one at the

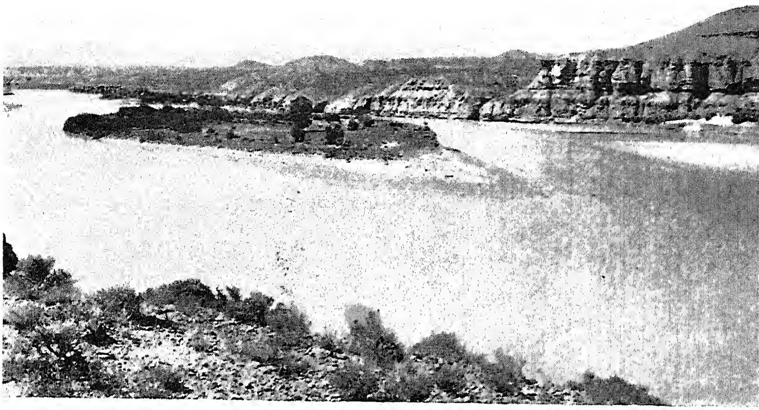
extreme right in this photograph. The shoals formed by these banks and bars are very trying to boatmen because the boats frequently ground on them in the shallow water. The material may be built up during times of high water to such an extent as to appear as a sand island at times of low water and become again a submerged island or shoal during high water. In some instances the islands persist for many years and become overgrown like the one here shown in midstream. In the middle distance are beds of Tertiary rock, craggy where the river has undercut them and formed precipitous bluffs, but gently rounded back from the bluffs where they have been formed under the slower processes of erosion.

PLATE 3B

A River Bend

Where the rocks are relatively soft or where for any other reason broad lowlands occur, streams develop winding courses more readily than in places where the high bluffs make lateral cutting by the stream difficult. The graceful crescent curve shown in this photograph is formed at the mouth of a tributary of the Green River which has helped to weaken the bluffs on the right. Here since the surface is low and rolling lateral cutting is made easy. Hard rock appears where the stream is eating into its banks at the right on the outer side of the curve. While the swift water is cutting away the bluff at the outer part of the curve the velocity of the water on the inner side is not able (because of checked velocity) to carry all of the sand and silt delivered to it. Here it drops a part of its load, thus filling the channel on the inner curve and there building up low, nearly flat, alluvial land. This process of cutting away the land in one place and building it in another is well understood as a normal process in river action, and is known to geographers as cut-and-fill. The sparse vegetation is characteristic of this sage-brush country.

PLATE 3



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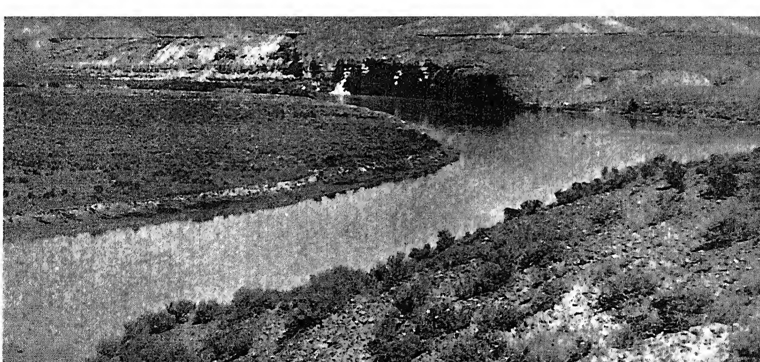

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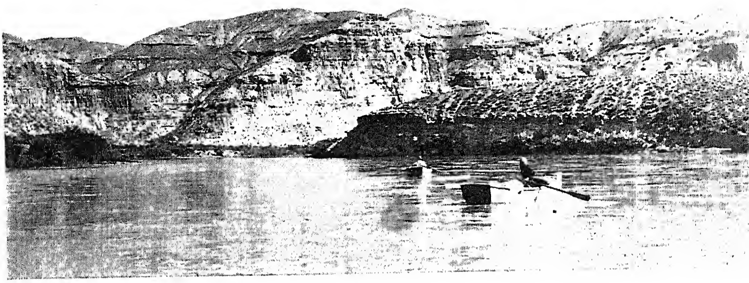
PLATE 4



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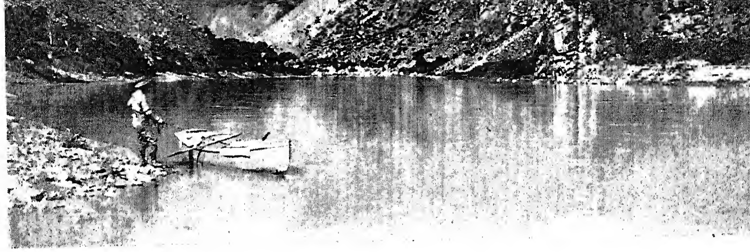

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PLATE 4A

Horizontally Bedded Rocks

The Green River beds lie nearly horizontal, as shown in this photograph, but as the mountains to the south are approached the river cuts across the eroded edges of several different geologic formations. These are soft and easily broken down, so that they do not seem conspicuous. Where the river leaves Wyoming it leaves also the rocks of Tertiary age and enters Utah in a channel cut in upturned rocks of Cretaceous age. These consist of marine shale and coal-bearing sandstone, that is, some of them originated as silt deposited in salt water during a period when the sea covered this region, and others as sand deposited on the shore or as mud and peat which accumulated in swamps. The broad valley in which Henry's River, locally called Henry's Fork, enters the Green is formed by erosion in a bed of the soft marine shale known to early observers in this region as the Salt Wells group and Sulphur Creek group, but later called the Hilliard formation.

PLATE 4B

Entrance to Flaming Gorge

The rocks of this "flaring, brilliant, red gorge" are vermilion in color surmounted by bands of mottled buff and gray. They are steeply inclined toward the north, rising from the water's edge in graceful curves and extending up the mountainside to a height of about thirteen hundred feet. The younger rocks on the outer side of the curve were first named "Henry's Fork group" after the river which enters the Green at the mouth of the gorge, and the older ones the "Flaming Gorge group." These group names are no longer used by geologists. The rocks of the Henry's Fork group shown in the photograph on the opposite page are now known as the Beckwith formation and are about the same in geologic age as those referred to on a later page as

the Morrison or the McElmo formation, in which the bones of huge dinosaurs have been found. Major Powell refers to a large fossil bone too heavy to carry with him, found in 1869 at Flaming Gorge. This was eight years before dinosaur bones were "discovered" in western America.

PLATE 5A

A Mountain Cut by a River

The Uinta Mountains are carved by erosion from a great fold or wrinkle in the face of the earth extending in a general east and west direction across the course of the Green River. There are minor wrinkles, cross-folds and spurs extending from the main mass which cause local depressions and irregularities of various kinds. One of the spurs of the main mass has been cut by the river in forming a short gorge known from its curved form as Horseshoe Canyon. Here the behavior of the river is peculiar. On emerging from Flaming Gorge it crosses a mile-wide opening, then plunges again abruptly into the side of Bear Mountain between precipitous walls washed by the racing water of the river. After a short excursion into the heart of the mountain where the walls attain a height of twelve hundred feet or more, the river makes a sharp turn and emerges from the gorge a mile below its entrance. Horseshoe Canyon is a good example of an inherited stream course. Just as the whole course of the Green River through the Uinta Mountains may be due to an inherited habit, so in this short canyon the course of the river was fixed on a higher plain ages ago. As the stream lowered its channel in the course of its down cutting, it encountered the hard rock which had formerly been buried.

PLATE 5

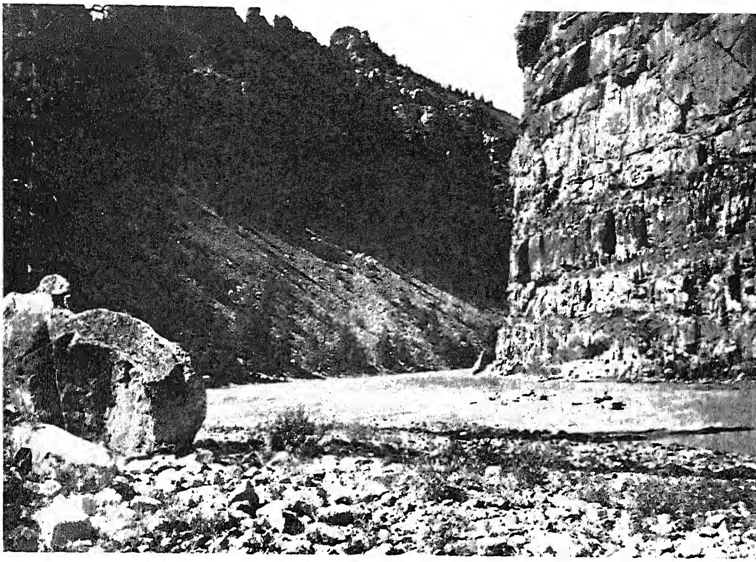

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PLATE 6

A

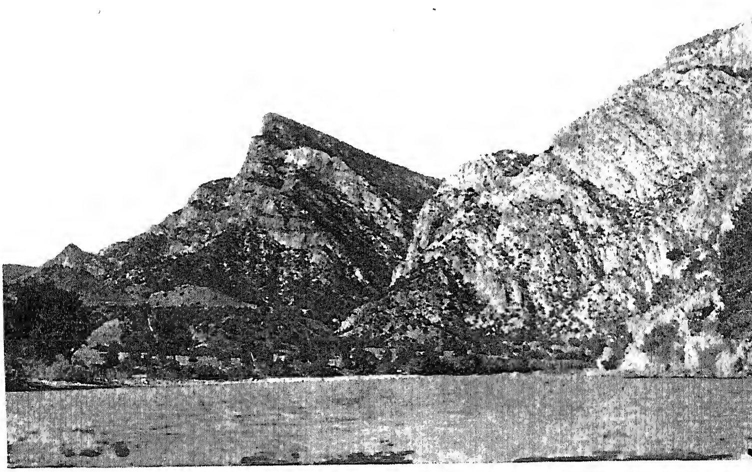

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PLATE 5B

THE ROCKS OF FLAMING GORGE AND HORSESHOE CANYON

On entering Flaming Gorge the river turns sharply to the right and flows for one and a half miles in a westerly direction diagonally across a belt of upturned layers of massive sandstone. The rocks exposed in the outer part of the gorge are those called by the early explorers Vermilion Cliff sandstone and White Cliff sandstone, but are now known as Nugget sandstone. This sandstone, about sixteen hundred feet thick, makes the dominating features of the landscape. Under this sandstone, that is, south of it in the belt of upturned rocks, are the brilliantly colored beds of the old Shinarump group, now known as the Ankareh shale, the Thaynes formation, and the Woodside shale. They are the rocks generally identified throughout the West as the Red Beds. The Nugget sandstone includes the yellow, pink, and red rocks characterized by conspicuous cross-bedding consisting partly of fossil sand dunes of early Jurassic time. This sandstone is the chief cause of many of the remarkable landscapes in eastern Utah and western Colorado. The still more brilliantly colored rocks below the Nugget belong in the Triassic system and are illustrated later in this volume where the red beds of Triassic age are described.

PLATE 6A

KINGFISHER CANYON AT BEEHIVE POINT

On emerging from Horseshoe Canyon, Green River turns southward through a small opening called Kingfisher Park, walled in to the northwest by nearly vertical cliffs of the brilliantly colored Woodside and Ankareh shales and the ledge-making Nugget and Thaynes sandstones, to plunge again into the hard, steeply upturned rocks of hard limestone and sandstone which rise to a height of about

twelve hundred feet in Kingfisher Canyon. Succeeding in cutting the wall of limestone and the hard quartzite, the river emerges from the canyon into a small park-like opening similar to the one just left behind. In this opening the walls rise in a succession of terraces to a height of twelve hundred or fifteen hundred feet, each step built of red sandstone with a face of naked red rock and a glacis clothed with verdure. So the amphitheater seems banded red and green as the sunlight plays on its walls, the rocks sending back roseate flashes and the verdure the shimmering green.

PLATE 6B

Upturned and Contorted Layers of Rock

Through the opening near Kingfisher Canyon passes the line of the great fault shown in Figure 1, where the earth's crust was broken when the Uinta Mountains were pushed up. The rocks near the line of faulting were fractured and weakened, allowing rapid erosion. Upturned and contorted, the rocks near this fault line offer unequal resistance to erosion and are therefore carved into a variety of irregular forms. The rocks of the main Uinta Range south of the fault line were pushed up thousands of feet higher than those north of the line, but since they were not greatly fractured, they presented greater resistance to erosion.

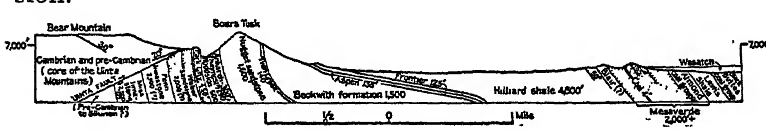


Fig. 1.

PLATE 7A

Entrance to Red Canyon

A little east of the mouth of Sheep Creek, a tributary stream which enters Green River from the west at the

mouth of Kingfisher Canyon, the river crosses the line of faulting and enters the high mountains in a narrow cut called Red Canyon. The walls of this gorge rise abruptly to heights of about twenty-five hundred feet, and are composed of the hard red quartzitic sandstone and pebblestone conglomerate which the early explorers called the Uinta group. These strata are not greatly disturbed and are not steeply inclined like those north of the fault line. Indeed they seem to be almost horizontal and to lie in their natural position. They appear layer on layer in the precipitous walls which rise in many places sheer from the bed of the river to heights of one thousand feet or more. The river current is swift and the rapids troublesome because of rocks in the channel through which, during some stages of the water, boats must be eased down by the use of lines. However, we ran these rapids without difficulty. In some places one side of the canyon may be somewhat sloping but the wall on the other side is bare rock from the water's edge up one thousand feet and then slopes back more gently to give footing to pines and cedars. It was here that Powell realized the principle that a slope must be viewed in profile if it is to be properly judged as to steepness and height.

PLATE 7B

Rocks of Red Canyon

The walls of Red Canyon are composed of red shale, sandstone, and conglomerate. In the rocks is much ironstone which oxidizes on exposure, giving rise to red oxide of iron, a pigment used in the manufacture of paint. The rocks are red because they are colored with this oxide. The pigment accumulates in natural basins in sheltered rocks and was formerly collected by the Indians for personal adornment.

The Uinta beds are more than twenty-five hundred feet thick. The river has eroded through this thickness but has not yet reached their base. No fossils have been found in the rocks, hence their geologic age is not known. But, as they lie under rocks of Carboniferous age, they are older

than the Carboniferous, and because some of them resemble rocks of Cambrian age at neighboring localities, they are supposed to belong in the Cambrian system. Others, however, are believed to be still older. From certain physical characteristics it is supposed that they originated as subaerial deposits, that is, that the material composing them accumulated above sea-level. The ripple-marked sandstones may have originated either as beach sand or as stream deposits, and the conglomerates as beds of gravel. Some of the shale has preserved imprints of raindrops that fell on it ages ago when it was soft mud. These fossil rain prints are mute but eloquent reminders that the climatic conditions of this very ancient period were not radically different from those of the present time.

PLATE 8A AND B

A PASSAGEWAY THROUGH A MOUNTAIN

The two photographs on Plate 8 are characteristic of scenes in Red Canyon.

The great arch of the Uinta Mountains through which the Green River passes is about one hundred and fifty miles long and thirty-five to fifty miles wide. There are minor wrinkles parallel to the main axis and numerous cross-folds which cause local depressions and irregularities of various kinds along the flanks of the mountains, and there are also many faults where the rocks were broken and where some parts slipped past other parts under the pressure that arched and fractured them. One of the greatest of these faults extends along the northern edge of the main mass of the Uintas and is crossed by the Green River at the mouth of Red Canyon.

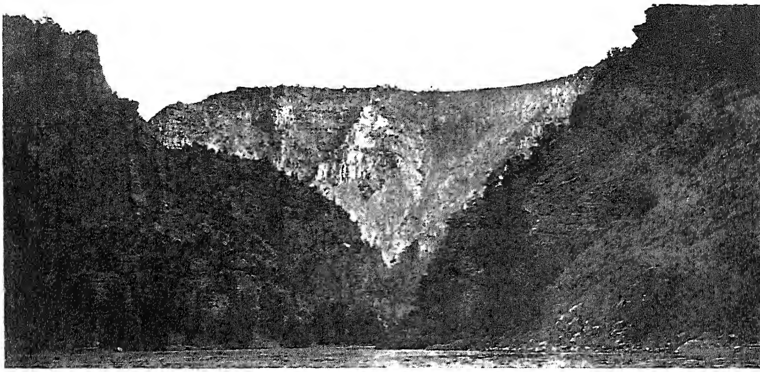
The great arch was carved by wind and weather, frost and stream, into a complex assortment of mountain peaks and gorges which now expose to view rocks which were once covered by thousands of feet of younger sediments. These range in geologic age from the very old rocks of the Cam-

PLATE 7

A

B

PLATE 8



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B

brian system to the younger rocks of Tertiary age. These now appear in great layers inclined steeply against the central mass of the mountains (See Fig. 2). Some of them are highly colored and all have been carved into a variety of interesting forms. Flaming Gorge, through which Green River enters the Uinta fold, so-called because of its bright colors, has been famous as a brilliant landscape ever since Major Powell first visited it in 1869.

The Uinta arch lies directly across the course of the river. The stream doubtless was there before the arch was formed and, having prior rights, maintained them, cutting for itself a way through the rising rocks, or the river may have developed on a higher plain during the erosion which followed the folding. There are two ways in which a river may make a passage through a range of mountains: The arch may have doubled across the previously established course of the river so slowly that the current was able to cut through the rising rocks and keep its pathway clear. Or, the present course may have been established at a time when the range was partly worn down and flanked with accumulations of broken rock and sedimentary material, so that a nearly flat plain was formed across the site of the range, but at a level higher than the present surface. This explanation of the river as superimposed is regarded as more probable than the once popular view that the stream maintained upon the slowly arching strata a course determined while these strata still lay flat. As the river, preserving its course, cut down through them the canyon remained narrow because of the hardness of the rocks, while great volumes of the softer material on the flanks of the range were eroded away. This principle is illustrated in the accompanying profile-section which portrays present relations near the eastern end of Brown's Park. A stream on the homogeneous rocks of the Green River formation would develop its course in accordance with surface conditions uninfluenced by the buried rocks. When in its down-cutting it reached the previously upheaved and truncated rocks under the Green River beds, it would find some of them hard and some soft, but it would persist in its inherited or superimposed course and

cut narrow gorges through the hard layers while it excavated "parks" on the softer beds.

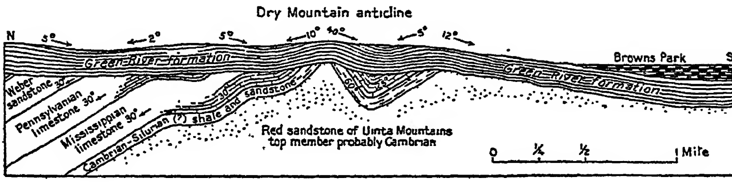


FIG. 2. Section near the eastern end of Brown's Park shows the older rocks were upturned and eroded and later covered with sediments (Green River formation) in Tertiary time.

PLATE 9A

ASHLEY FALLS

Ashley Falls is a misnomer, for there is no vertical drop of the water. It is a "rapid" and at certain stages of water a difficult one to overcome. It probably was this among others in Red Canyon which the old Indian named Pariats had in mind when he said to Major Powell: "Water-pony (boat) heap buck; water catch 'em, no see 'em Injun any more, no see 'em squaw any more, no see 'em papoose any more." This rapid, situated about four miles above the mouth of the canyon, is caused by a pile of boulders fallen into the river from the cliff which rises almost vertically two hundred or three hundred feet above the water on the right. The large boulder in the middle of the stream is thirty or forty feet in diameter. Its size may be judged by comparison with the man and boat in the water at the left. Although former expeditions had experienced difficulty here, our party ran the rapid safely, though trouble following the breaking of an oarlock was but narrowly averted.

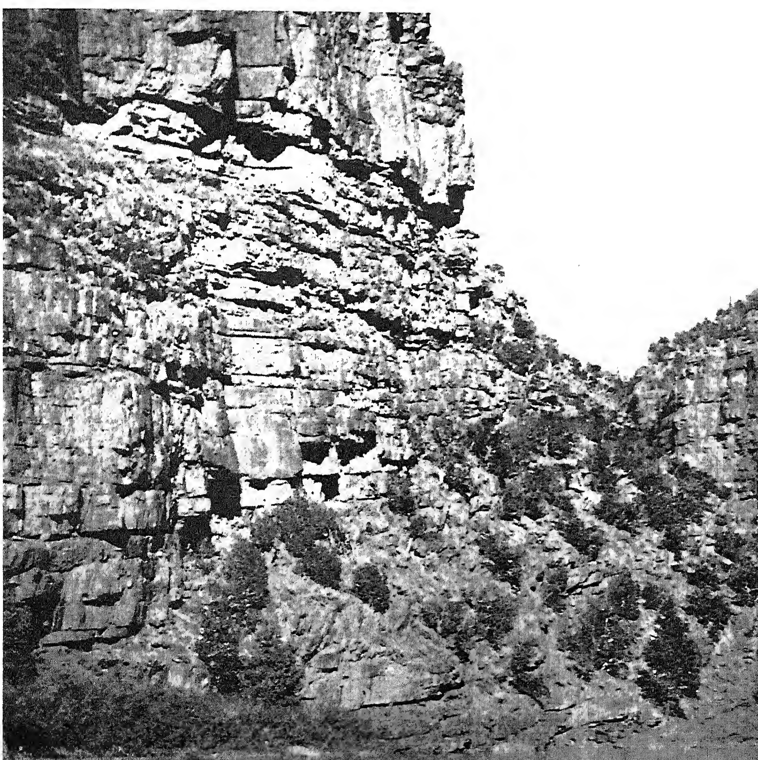
PLATE 9B

DETAILS OF THE WALLS IN RED CANYON

Below Ashley Falls the canyon narrows again, and the high walls which confine the plunging waters rise to great

PLATE 9

A



B

PLATE 10

A

B

heights, naked and almost lifeless, in nearly vertical faces. A few stunted trees and desert shrubs find foothold in rock crevices and eke out a starved existence. In such faces the character of the rocks may be examined minutely. Layer on layer may be observed resting where the sand and mud from which they were formed were laid down long ages ago. In these perfectly exposed rocks the expert in such matters may read the story of their formation. Some of these layers of rock were formed in running water, others originated as beds of wind-blown sand, and still others as mud deposited by some flood and later exposed to the rain and the sunshine of ages long gone by. These layers of rock are the pages in the story book of geology, wherein may be read the history of the earth's crust.

PLATE 10A

LITTLE BROWN'S PARK

The river leaves the deep, narrow gorge of Red Canyon somewhat abruptly and enters a broad open valley the western end of which was originally called "Little Brown's Hole." The designation "Hole" grew out of the custom of the early trappers of picking out some sheltered or favorable spot in which to "hole up" during stormy winter weather, in other words a retreat, a home place. Later the whole valley was renamed Brown's Park. This part is a broad hollow between O-rav-i-yu-kuts plateau on the south and O-wi-yu-kuts plateau (now called Cold Spring Mountain) on the north. These plateaus reach heights of more than eight thousand feet above sea-level, or about twenty-five hundred feet above the floor of the valley. On them stand mountain peaks which rise to still greater altitudes. Mt. Cullum, on the south, has an altitude of eight thousand nine hundred feet, and Diamond Peak, on the north, an altitude of nine thousand feet above sea level. This so-called park was once a great valley or elongated hollow in the ancient rocks six to eight miles wide and more than twenty-five hundred feet deep. The hollow, perhaps an ancient river valley or a lake bed, was later partly or wholly filled with

sand, gravel, and silt, called the Brown's Park group, but now known as the Bridger beds. From the foot of Red Canyon to the gate of Lodore, the Green River occupies the ancient valley, and in re-excavating it, has removed much of the Tertiary material, exposing again the old quartzites of the Uintas now revealed on either side of the river in precipitous bluffs at distances of three or four miles.

PLATE 10B

Swallow Canyon

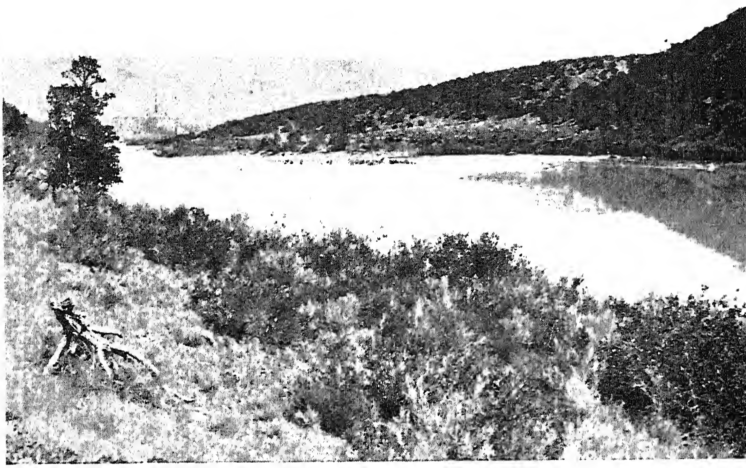
Near the western end of Brown's Park a spur of the ancient quartzites of the plateau to the south escaped erosion and was buried by the sand and gravel of the Bridger beds. Later when the river partly re-excavated the ancient valley its course was fixed over the buried spur. As it cut downward the river became intrenched in the hard rock where it succeeded in cutting only a narrow passageway during the time required for excavating the broad valley in the softer material. The walls of this canyon are not particularly high but are steep and rugged. Swallow Canyon is so named because of the numerous "adobe" swallows' nests found in its walls.

PLATE 11A

The Open Valley of Brown's Park

The scenery along the course of the Green River is not an unbroken succession of gorge, cliff, and crag. The strong, rugged features are relieved here and there by open parks, grassy glades, and gentle slopes. In the view here illustrated some of the milder features are exhibited. In the distance may be seen one of the high plateaus which inclose the park. At the eastern end of Brown's Park, just north of the Gate of Lodore, Vermilion Creek enters the Green from the east. This creek doubtless takes its name from the highly colored rocks across which it flows on its way to the river, and from which it collects mud that stains its flood waters. A few

PLATE II



A

B

PLATE 12

A

B

miles northeast of its mouth the same rock formations as those exposed in Flaming Gorge are upturned and truncated, as shown in the accompanying profile section.

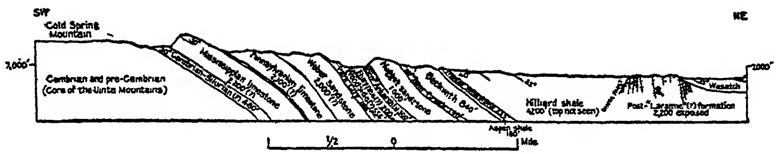


FIG. 3. Section of beds from upper part of Hilliard shale (Cretaceous) to Cambrian, measured near Vermilion Creek (after A. R. Schultz).

PLATE 11B—THE GATE OF LODORE

Near the east end of Brown's Park the Green leaves Utah and enters the State of Colorado. A few miles east of the boundary the river turns southward and leaving the open valley of Brown's Park enters an abrupt gash in the mountain range which seems the embodiment of picturesque simplicity. By the way of this gash the river crosses the main range of the Uinta Mountains. The entrance to which Dellenbaugh refers as "that magnificent and unrivaled portal, the Gate of Lodore," is a narrow gorge whose walls rise in precipitous barren cliffs to heights of about two thousand feet above the river. To the west O-rav-i-yu-kuts plateau rises probably eight thousand feet above sea-level. Above its general level Mount Cullom rises nine hundred feet higher. East of the canyon this plateau is terminated on the south by Escalante Peaks. The major features of the Uinta region, even the largest, like the great plateaus and the mountain peaks, result almost wholly from long erosion of the uplifted masses of rock. A thickness estimated at thirty thousand feet has been removed. In fact, these impressive plateaus and mountains are but relatively small remnants of the great Uinta fold.

PLATE 12A AND B—HEAD OF LODORE CANYON

Once in the canyon, landscapes appear which for weird fascination and awe-inspiring charm are surpassed in few

places. The red and purple walls rise cliff on cliff in naked splendor, in many places sheer from the water's edge. The drainage from sixteen thousand six hundred square miles of territory here makes a stream three hundred feet wide. Enough water passes through this canyon each year to cover nearly four thousand square miles with water one foot deep. At times of low water the river is only a few feet deep, but at flood time the sand, gravel, and boulders of the channel are stirred to great depths. Borings near the mouth of the canyon at the site of a proposed dam which would control the flood waters of the Green River for purposes of irrigation, indicate that a channel has been scoured out to a depth of one hundred and three feet below low water level, but six miles below the proposed dam the drill penetrated to a depth of one hundred and sixty feet without encountering bed rock. This means either that the river scours to a depth of more than one hundred and sixty feet, or that the canyon was once deeper than it is now and has been partly refilled with sand and boulders.

PLATE 13A

Rocks of Lodore Canyon

Most of the rocks exposed in Lodore Canyon are the ancient sedimentaries which constitute the Uinta Mountains. The harder layers were once sand, and the softer layers mud. In the course of the ages that have elapsed since the material accumulated, the sand has hardened to quartzite, and the mud to shale. As these hard rocks are undercut by the river and disintegrate in the weather, portions of the wall fall away, leaving in many places naked faces of rock with no hint of verdure. However, in some places fragments gather into accumulations of slide rock, called talus, like that in the narrow slope shown at the right. The shaly layers crumble more readily than those consisting of hard quartzite, giving rise to crags, ribbed walls, pinnacled crests, and a variety of those erosional forms which characterize a region where the rocks show unequal resistance to erosion.

PLATE 13

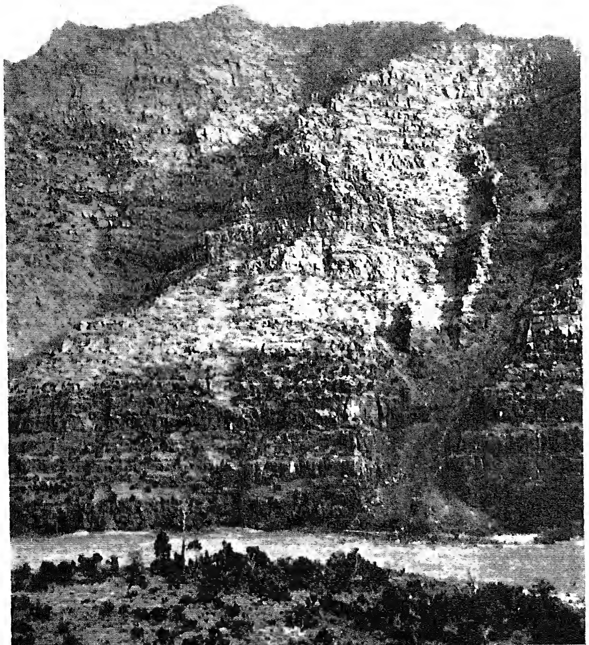


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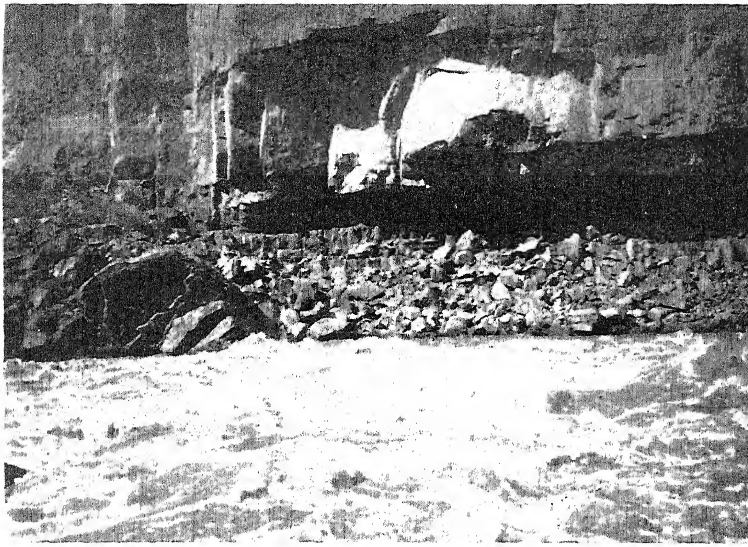
Plate 14



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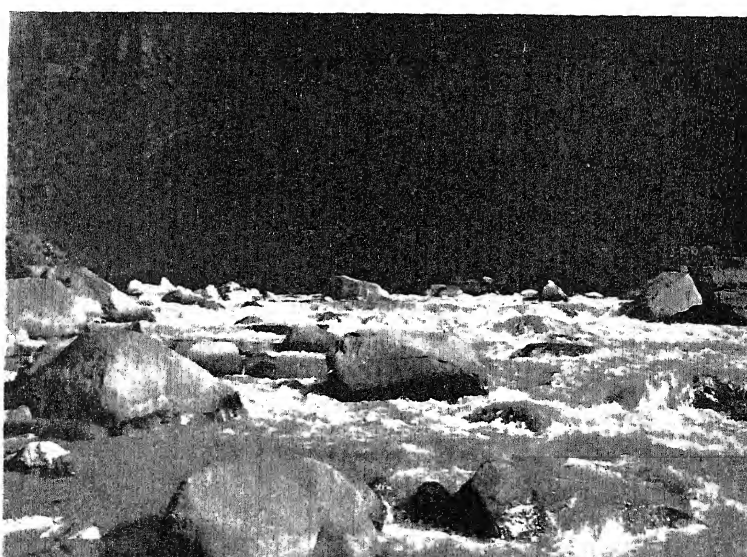

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PLATE 13B

Disaster Falls

All who have passed through the canyon of Lodore agree that Disaster Falls is a bad rapid and that running it with loaded boats is out of the question, even though the portage over polished boulders to its foot is heart-breaking labor. Here mishap overtook the original exploring party, a fact which accounts for the name of the rapid. Our party ran the empty boats through. With their ordinary load they would doubtless have struck slightly submerged or exposed rocks and been damaged or lost. The shore is several hundred feet wide with a few scrubby pines where there is room enough for them between the great blocks of rock. The boulders are so large and numerous as to make traveling, even with an ordinary load, very laborious. Measurements by leveling indicate that the steepest part of this rapid has a fall of five feet in the first seven hundred feet, and twenty-one and one-half feet in the next nineteen hundred and sixty-eight feet. The water is shallow and the channel rocky. An island of boulders has been formed at the lower end which divides and spreads the water. About five hundred feet down stream from the foot of upper Disaster Falls is the rapid called Lower Disaster Falls. Here the water descends fourteen feet in about twelve hundred feet. Here, too, our boats were lightened before the rapid was run. This photograph may be compared with the illustration shown opposite page 27 of Major Powell's "Exploration of the Colorado River of the West" (Government printing office, 1875). The scene is identical. Comment would be superfluous.

PLATE 14A

Irresistible Water and Immovable Rocks

In the canyon of Lodore the irresistible river has come squarely into conflict with the immovable mountains. The

water descends turbulently over rapid after rapid, making an aggregate fall of almost three hundred feet in seventeen miles. Dellenbaugh found the canyon almost one continuous rapid throughout its length and confirms the statement in Jack Sumner's notes that it is "a hell of foam." However, some of the exploring party were more poetically inclined. In casting about for a name for the canyon, they were reminded of Robert Southey's description of the roaring, plunging waters of Lodore. In this canyon are situated Disaster Falls (where one of Powell's boats was wrecked), Triplet Falls, and Hell's Half-mile, where the river "tumbles with a descent of twenty-five feet in a channel beset with great numbers of huge boulders." We found that at the lower end of Hell's Half-mile the channel was so choked with boulders fallen from the walls that it was impossible to get a boat between them. Here the Kolb brothers found that a cliff had fallen and scattered rocks were piled on both sides in a riotous mass. The impression gained in this canyon is summed up in the statement that its walls and cliffs, its peaks and crags, its amphitheaters and alcoves tell a fascinating story of beauty and grandeur. The wonderful scenes need no embellishment to make them impressive. The exaggerated illustration of Disaster Falls shown in Major Powell's "Colorado River of the West" (facing page 27) is wholly inexcusable because no such scene exists.

PLATE 14B

How a Rapid is Formed

The rapids in the canyon of Lodore are formed by the river flowing over great masses of boulders which have fallen from the canyon walls or which have been carried by the current from some place farther up stream. Some of the boulders are angular, others partly rounded and polished. When rocks fall from the walls, the river washes the smaller fragments down stream, leaving where they fall those that are too large for it to handle. At the rapids

these boulders occur in sufficient number partially to dam the stream. In time these are removed or rearranged by the current. The shape of the channel changes with every flood. The smaller boulders are moved by moderately high water, but some are so large that they remain where they were fifty years ago. However slow the change may be as compared with the span of human life, as river history goes, a rapid is a thing of the moment, shifting position now here, now there, coming and going with constant change.

The manner in which a rapid may be formed is graphically told by E. L. Kolb in his excellent book entitled "Through the Grand Canyon from Wyoming to Mexico." While Kolb was in Lodore Canyon one stormy night a part of the wall a quarter of a mile from camp slid off into the river. Kolb, who knew that the wall above him was as likely to fall as that a quarter of a mile away, frankly admits that the reverberating thunder of thousands of tons of rock sliding down the three-thousand-foot precipice made him feel "a little nervous."

PLATE 15A

Wheatstack Rock

One of the picturesque forms of erosion near the lower end of the canyon of Lodore has a form which reminded some misguided person of a stack of wheat. It is an unfortunate circumstance that some observers of the wonderful objects which nature provides for our admiration and instruction seem unhappy unless they can see in these objects some resemblance to familiar things, usually of a belittling nature. It is not a pleasurable thought that this impressive mass of rounded and beautifully colored rock must be associated with a stack of wheat. "Wheatstack" Rock presents a beautiful and impressive exhibit of strata formed one above another by the deposition of sand and silt millions of years ago. On these strata is imprinted the record of that ancient time, a record which lay buried through untold ages, but is now brought to light and conspicuously exposed.

PLATE 15B

Dunn's Cliff

A scene in the lower part of Lodore Canyon.

Plate 15

A

B

PLATE 16

A

B

PLATE 16A

Difficult Boating in Lodore

This photograph tells its own story.

Near the mouth of Lodore there are many boulders of iron-stained quartz and limestone whose polished surfaces make travel over them difficult. This rapid was found especially annoying.

PLATE 16B

Rocks Near the Mouth of Lodore

Near the southern end of the canyon the rocks above the quartzites of the Uintas may be seen in the walls. The stratified rocks dip southward so that the Redwall limestone and the underlying Lodore shale which near Disaster Falls outcrop in the face of Dunn's cliff twenty-five hundred feet above the river pass under water about three miles farther to the south. The Lodore beds, about four hundred and sixty feet thick, consist of soft shale, sandstone, and conglomerate. They fill hollows which once were valleys in the still older rocks in the same way that the Bridger beds once filled Brown's Park. The origin of these rocks may be described as follows: For long ages before the Lodore beds came into existence the quartzites of the Uintas had been exposed to the weather and had been eroded into low hills and broad shallow valleys. At some later time, supposedly in the Cambrian period, a change occurred, causing the streams of that ancient epoch to deposit their burdens of sand and gravel in the valleys and on the old flood plains. In this way the low places were filled until the accumulating alluvium finally buried the neighboring hills. Later the sea spread over the plain thus leveled up, and in it accumulated the limy ooze which hardened into the Redwall limestone.

PLATE 17A

Sharply Flexed Strata at South End of Lodore Canyon

The craggy, ribbed appearance of the rocks in the center of this photograph is due to erosion on upturned layers of sedimentary rock of unequal hardness. These rocks consist of thin strata of hard sandstone and relatively soft shale. Under the action of rain, frost, and wind, the softer material is removed, leaving in relief the more resistant layers of rock. These strata were laid down in a practically horizontal position by the deposition in water of sand and silt. For many ages they lay buried and were subjected to hardening processes. When the mountains were pushed up the buried strata were here raised, tilted, and exposed to erosion. These upturned rocks are the same as those crossed in Kingfisher Canyon. At one time "before ever the mountains were formed" these strata extended continuously across the site of the Uintas.

PLATE 17B

Echo Cliff

On emerging from between the high, ribbed walls of the lower part of Lodore Canyon the river enters a little park where it is joined by Yampa River. During this short journey it crosses again the brightly colored red rocks seen in Flaming Gorge. But here the layers of rock are inclined toward the south rather than in the opposite direction, as they were north of the range. Long ages ago, before the top of the Uinta uplift was eroded away, these beds extended up the southern slope and over the top of the great arch. The park at the mouth of the Yampa has been described as surrounded by "inaccessible" walls which rise six hundred feet or more above river level. The word "inaccessible" must be interpreted liberally, for it is not impossible to scale them. Such exaggerated statements, viewed in the cold

PLATE 17

A

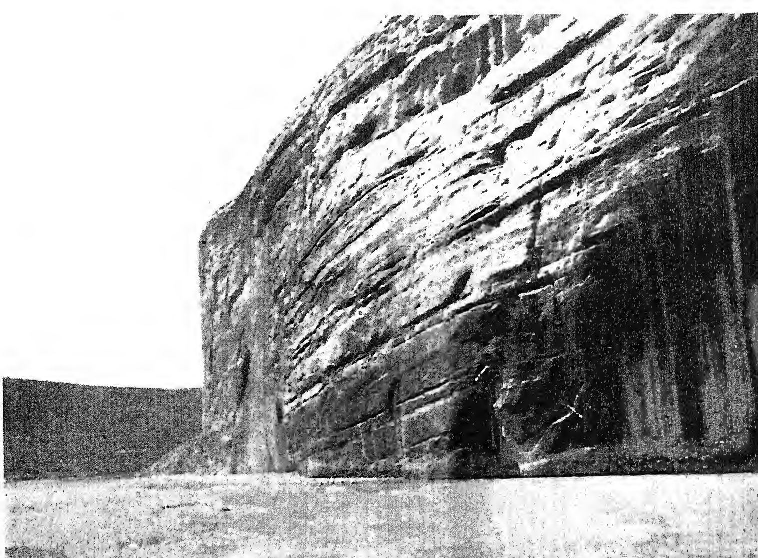

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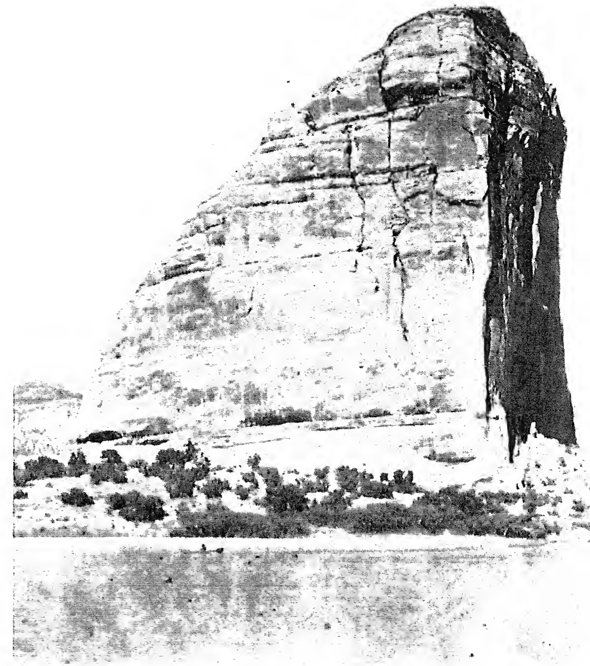
Plate 18

A



B

light of dictionary definition, may be ill-advised, but in a popular description of the truly remarkable features, they seem almost pardonable. Echo Rock, six hundred to eight hundred feet high, rises sheer from the water, its eastern face practically vertical. It is a great mass of reddish-yellow rock made up of thick layers gently inclined toward the south. The vertical streaks which show in the photograph are water markings on the surface and have nothing to do with the characteristics of the rock.

PLATE 18A

Mouth of Yampa Canyon

Near its junction with Green River the Yampa or Bear River has cut through massive light gray sandstone into the thinly bedded rocks below, making a cliff north of the river possibly one thousand feet high. On the opposite side the wall is rough and craggy. This is obviously due to difference in the character of the rocks. The Atlas of Uinta Mountains indicates that the rocks of the north wall of Yampa Canyon belong in the "Lower Aubrey group." These, while relatively soft, form vertical ledges in many places. Those of the south wall belong to the "Upper Aubrey group," rocks which are hard and which, on weathering, exhibit rough faces. Farther to the north the Escalante peaks (a name given in honor of a Spanish priest) are remnants of the still more resistant rocks of the Redwall formation.

The Yampa drains about 4,000 square miles of country and supplies to the Green enough water in one year to cover 1,000,000 acres, or more than 1562 square miles, one foot deep.

PLATE 18B

South End of Echo Rock

Echo Cliff is the side of a long tongue of rock or spur of the Uinta Mountains which forms a peninsular precipice

around which the river turns abruptly to the west and then to the north, doubling sharply on its course. This spur terminates in an impressive mass of rock rising about six hundred feet or so above the water and having vertical or steeply sloping sides. Some conception of the size of this great mass of rock may be obtained by comparison with the man and the boat.

Directly across the river from this rock is a small flat or flood plain hemmed in by high walls of rock, known as "Pat's Hole," where Pat Lynch, an eccentric Irish pioneer, lived in a little cabin for a long time. Far removed from intrusion or inquisitive neighbors, he was free from the limitations of civilization for many years. Happy Pat!

PLATE 19A AND B

NORTH END OF ECHO PARK

Echo Park, which is in this general region but which is not shown in the photographs on the opposite page, is a small flood plain just large enough for a farm, already fenced with high walls of gray homogeneous sandstone to which access may be had only through the canyons of the Green and the Yampa rivers. The attractive scenes in this park and neighboring places will be easily accessible when the Moffat road is completed along the surveyed line passing through this park by way of Yampa Canyon. Photograph 19A is a scene in this park west of Echo Cliff, looking northward toward the Uinta Mountains. Plate 19B is a nearer view of the same scene. Here the river enters Whirlpool Canyon, a name which characterizes the erratic course of the river, for in winding in and out among the crags and around the rocky spurs the water is greatly agitated, forming many whirlpools.

Peak of Wolf Mountain in the middle distance.

PLATE 19

A

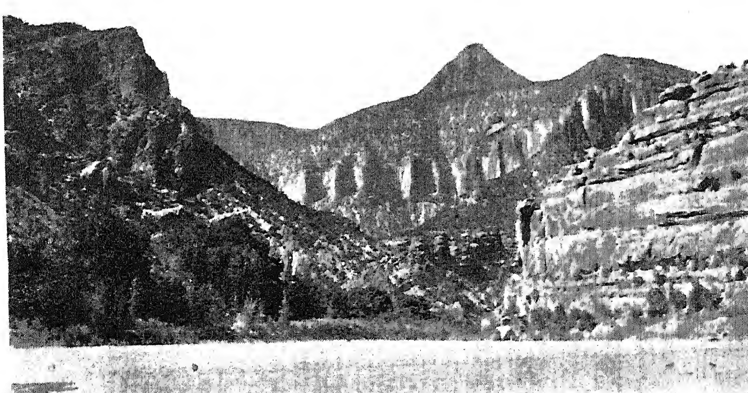


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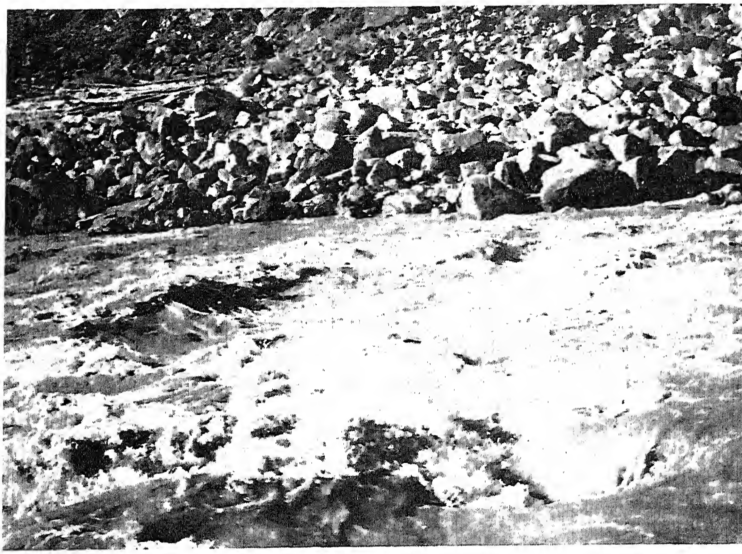
PLATE 20



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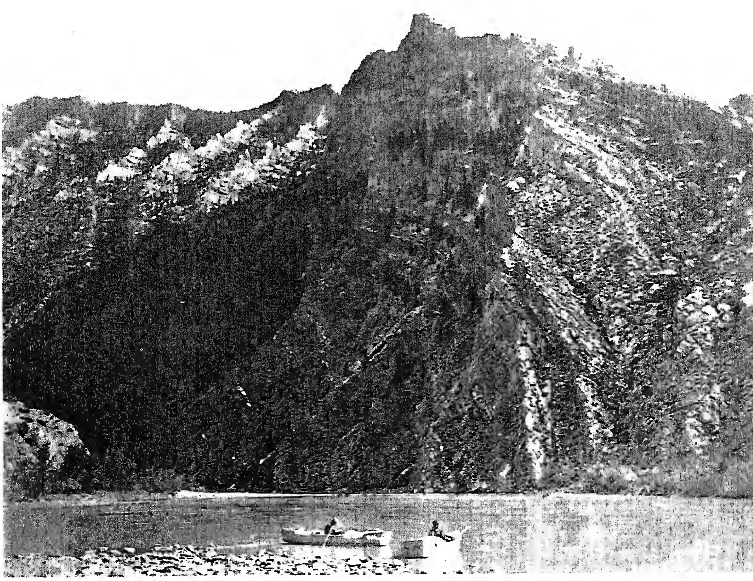

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PLATE 20A

The "Suck" of a Whirlpool

Much has been said of the whirlpools formed below rapids. Some writers have emphasized the danger of being drawn into them. A few, however, write belittling such danger. As the swift current of a rapid enters the quieter waters below, lateral reverse currents are set in motion which result in some instances in a rapid whirling of water with a funnel-shaped depression in the center due to the escape of some of the water below. A swimmer or any small object might readily be sucked beneath the surface in such a whirling mass. Boats may be whirled about and possibly capsized in the larger whirlpools. But there is little danger in the smaller ones.

PLATE 20B

Arched Rocks at the Mouth of Whirlpool Canyon

On leaving Echo Park the river turns westward and cuts diagonally across the eroded edges of the upturned sedimentary rocks at the base of the Uintas. In so doing it passes entirely across not only the red beds exposed in Echo Park but the still older beds of Carboniferous age, and once more enters the ancient quartzites of the Uintas. These, as well as the younger formations, are steeply upturned. The strata rise abruptly from the water, their eroded edges describing long sweeping curves. Here the red and yellow of the younger rocks give place to the pink and purple of the older ones which are unevenly eroded into sharp pinnacles and narrow, thin-crested ridges. The evergreen trees which grow in considerable numbers here soften the hard monotony of the rocks, giving pleasing variety to the landscape. This is near the southern end of the rainbow of highly colored strata begun on the north side of the Uintas, the center of which, over the present-day mountains, has been eroded away.

PLATE 21A

Mouth of Whirlpool Canyon

It may seem a far cry from the character of rocks formed millions of years ago to a name used in modern geography, and yet the name Whirlpool Canyon results directly from the character of the ancient rocks exposed in its walls. The layers of sedimentary rock in this region are steeply upturned on the south flank of the Uintas. The river follows the line of outcrop of the rocks, cutting across the eroded edges of the strata entirely through the series of alternating hard and soft layers steeply tilted and in some places standing on end. In these upturned rocks the river encountered a variety of conditions. Erosion was easy here and difficult there. The hard layers resisted erosion and now stand out as pinnacles on the sky line or as crags and buttresses in the walls, whereas hollows formed where the softer layers were eroded out. The net result is a rugged character of walls which tempted Powell to call this Craggy Canyon. Around the jutting buttresses and into the recesses from which the soft rock was removed the river follows a zigzag course, rolling, boiling, and churning as though agitated by something beneath the surface. Thus are the waters set eddying and spinning in whirlpools by projecting rocks and short curves, and so "waltz their way through the canyon."

PLATE 21B

Below Whirlpool Canyon in Island Park

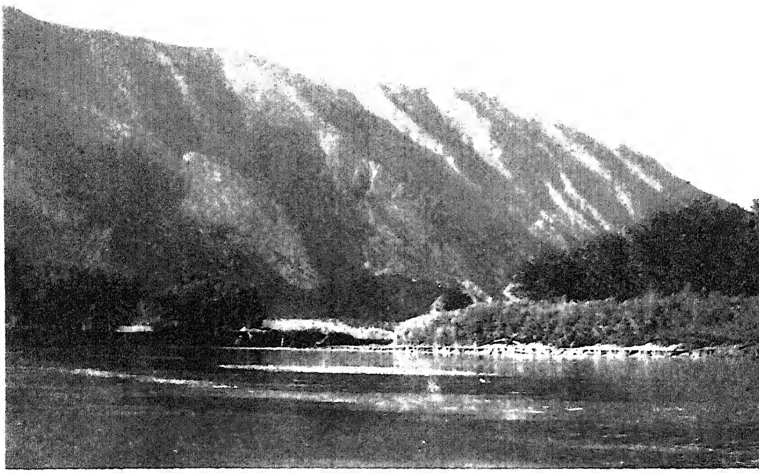
While the walls in the narrow, rugged part of Whirlpool Canyon are so precipitous that they make the depths seem a trifle gloomy even at midday, this narrow part ends about four miles above its mouth at a bad rapid situated in a narrow passage between steep walls. Here the rocks, more than ordinarily resistant, rise eighteen hundred to twenty-four hundred feet above the river. Because of their varied

PLATE 21

A

B

PLATE 22



A

B

character and disturbed condition they have been carved into a great variety of curious and fascinating forms. But just below its mouth are found flowered turf and shady retreat.

PLATE 22A

Island Park and Yampa Plateau

The river emerges from Whirlpool Canyon near the boundary between Colorado and Utah, and enters a beautiful opening in the mountains called Island Park. Here the river broadens, meanders widely through verdure-clothed bottom lands, and encloses several sandy islands. In this rest camp the river pauses as if with a sigh of relief after a hard journey. The opening is due to erosion in the relatively soft Red Beds which occupy the trough of a syncline or down-warped part of the earth's crust. The trough inclines toward the west and is technically known as a pitching syncline. South of it a corresponding up-warped wrinkle forms the western end of Yampa Plateau. Red shale and sandstone occupy the trough, and the older and harder rocks outcrop in concentric ridges around its eastern end, except where their continuity is broken by a fault. After meandering through the park, the river approaches Yampa Plateau and flows at its foot for a couple of miles or more before cutting into its highlands. This tableland ends a few miles west of the Utah-Colorado boundary in a westward-pitching anticline in which the hard rocks of the plateau bend sharply downward to the north, west, and south and disappear beneath the soft Red Beds and the shale of Cretaceous age which have been eroded down to form the surrounding lowlands.

PLATE 22B

Just Below the Entrance to Split Mountain Canyon

The river turns southward from Island Park and enters through a "flaring, brilliant gateway" into a narrow gorge

called Split Mountain Canyon. The name, though beautifully expressive of appearances, is unfortunate in some respects. For this canyon is not what it seems, the gash not being due to a split in the mountain. It denotes a superimposed course of the river, fixed at a time when Split Mountain was buried under rocks which have since been eroded away. In passing from Island Park into the canyon the river crosses the eroded edges of the brightly colored Nugget or Vermilion Cliff sandstone, and the still more brilliantly colored beds of the Ankareh shale, and enters the hard rocks of the Park City beds and other formations which are inclined steeply on the flanks of Split Mountain. The harder layers of these rocks show how the strata, once lying in a horizontal position, were arched, warped, and broken during the upheaval that formed the mountains.

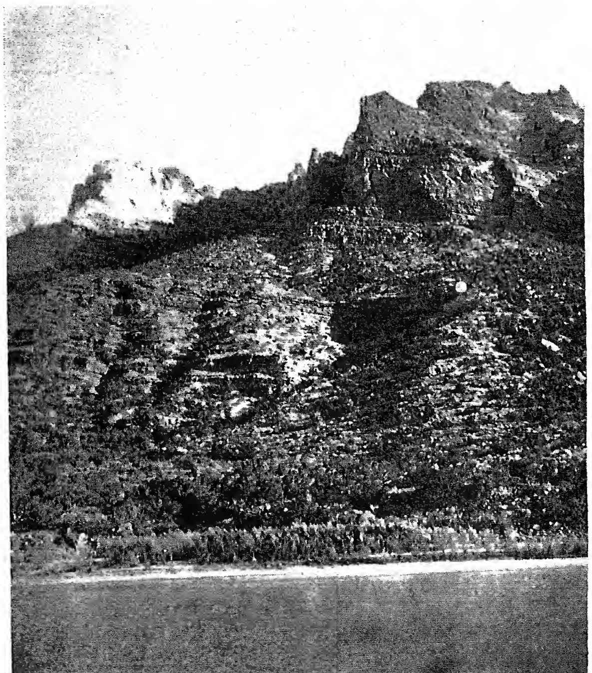
From a height such as the one shown on Plate 22B one may gaze over the park to the north with its island groves reflected by the deep, quiet waters of the meandering river. Rich meadows stretch out on either hand to the verge of a sloping plain that comes down from the distant mountains. This plain is of almost naked rock, in strange contrast to the meadows: blue and lilac-colored rock, buff and pink, vermilion and brown, all these colors bright and clear. Powell was tempted to call this Rainbow Park, a name which has since been applied to an area a few miles farther to the southwest.

PLATE 23A

Etched and Embossed Walls

Where the rocks are upturned, exposing to the elements the edges of the strata, the soft, easily-eroded parts are worn away, leaving those parts which resist erosion more strongly standing as crags, pinnacles, and natural monuments. Where the strata are more nearly horizontal, they are cut by erosion into forms quite different from those in a region of upturned rocks. Where the strata consist of alternate hard and soft layers, the softer ones are worn

PLATE 23



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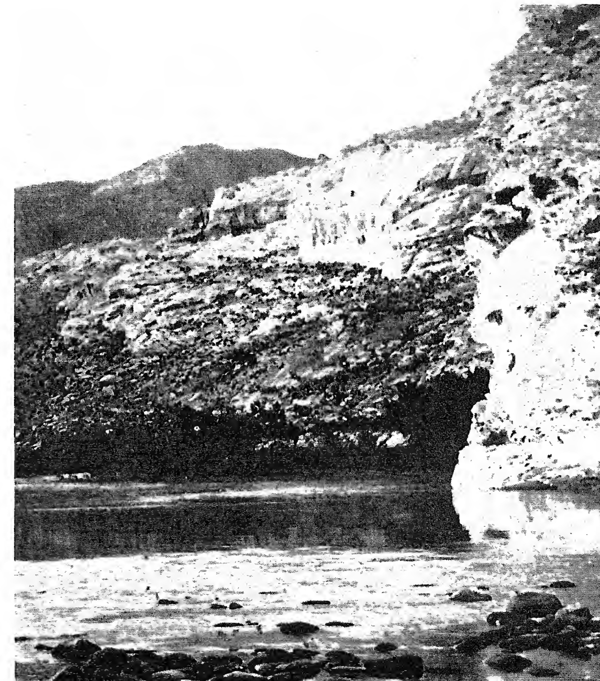

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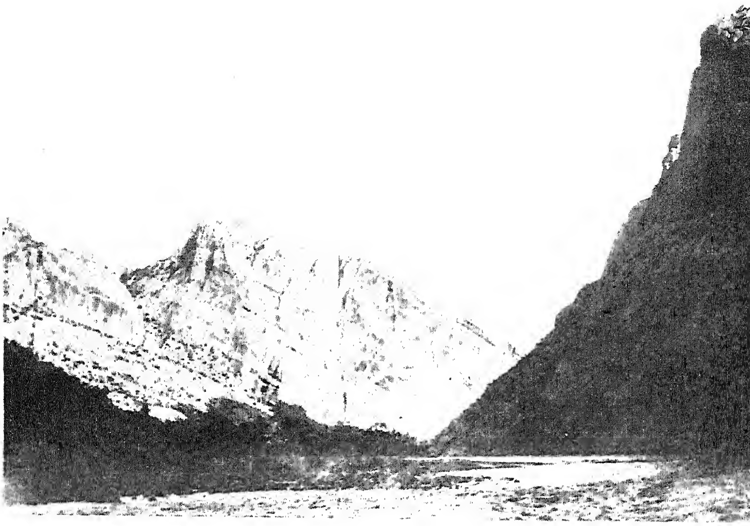
PLATE 24



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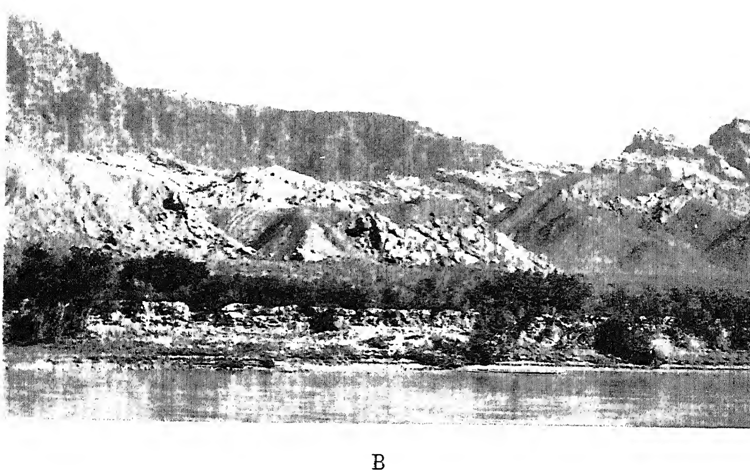


B

away by rain, frost, and wind more rapidly than the hard parts, which are left as ledges or terraces in the canyon walls. The strata in Split Mountain are composed of many layers of hard rock separated by layers of softer rock, and range in position from horizontal to nearly vertical. For this reason the land forms vary from even-surfaced highlands characteristic of flat-lying beds to the jagged ridges and serrate crests of steeply upturned beds.

PLATE 23B

Walls of Split Mountain Canyon

Split Mountain is a ridge produced by the arching of strata consisting chiefly of hard, craggy red sandstone which ranges in geologic age from Carboniferous to Jurassic. The axis of the arch is inclined toward the west. The younger rocks upturned around the western end of the mountain are truncated and crop out in concentric bands at the end of the plunging arch. The older ones in the middle of the anticline are more gently flexed and outcrop in the walls of the canyon in long, sweeping curves. The river enters the mountain to the center of the anticline, and then, following its axis, turns to the southwest, "splitting the mountain ridge for a distance of six miles." At the upper end of the canyon the river is three hundred and fifty feet wide and the canyon "only seven hundred feet from wall to wall at a height of about two hundred feet above the water." Rock slides must inevitably occur frequently in such walls. Kolb noted one which the river had not yet cleared away and which had made a bad rapid.

PLATE 24A

The Exit from Split Mountain Canyon

At the southern end of Split Mountain Canyon the river cuts again across the eroded edges of the strata traversed

on entering the canyon but in reverse order. Here they incline toward the south and disappear under the lowland floor of a down-warped part of Ashley Valley called the Jensen Syncline. At some former time they extended over Split Mountain in a great arch, most of which has since been eroded away. From between the rugged walls of hard rock in the narrow gorge, the river cuts the phosphate-bearing limestone of the Park City formation, crosses the still younger red beds, and finally emerges into the open country where the relatively soft rocks of Cretaceous age have been partly eroded away and the country reduced to a rolling plain. These soft younger rocks have been preserved here, whereas they have been entirely removed from the uplifted region about Split Mountain. They were preserved south of the mountain because the earth's crust was here bent downward as the rocks were thrown into folds and the soft beds lowered to a position where erosion is not vigorous. This is the southern end of the rainbow.

PLATE 24B

Dinosaur National Monument

On leaving Split Mountain Canyon the river flows southward for a distance of three miles, then turns abruptly to the west and north, retracing its course to the foothills. On reaching the hills it makes another turn to the west and then to the south and continues across the rolling plain. This part of its course is chiefly in open country where the soft marine Cretaceous shale has been eroded more extensively than the hard rocks of the adjacent mountains. Near the northern end of the loop is Dinosaur National Monument or Park, a tract of eighty acres of land reserved as public domain for the purpose of preventing unwise exploitation of a remarkable deposit of fossil bones of the extinct giant lizards called Dinosaurs. Here was the home, long ages ago, of *Aptosaurus Louisae,* the largest creature, so far as is now known, that ever walked the

earth. Southwest of Dinosaur National Monument the river holds to a southerly direction of flow, again crossing the Jensen Syncline. Near Jensen it is close to the western end of another plunging fold called Section Ridge Anticline, where the hard rocks of the southern part of Yampa Plateau turn downward and pass beneath the softer rocks of Ashley Valley.

PLATE 25A AND B

Ashley Valley

South of Jensen the Green River flows in a broad valley across the soft marine Cretaceous rocks known to geologists as Mancos shale. Here broad flood plains have been formed by the river working laterally after the manner known as cut-and-fill. As this is in a semi-arid region, the shale uplands which appear in the distance in Plate 25B are barren, whereas the flood plains watered by the river at times of flood are fertile and productive. There have been epochs in the history of the Green when the stream deposited sand and gravel, building up its course rather than perpetually cutting it down. During such an epoch of upbuilding the Green laid down the great masses of gravel shown in the distance in Plate 25A. The gravel beds originally extended entirely across the valley, but some change occurred, causing the river to re-excavate its bed and carry away some of the gravel which it had dropped. Hence the broad flood plain is bordered by gravel bluffs. These gravel beds contain small amounts of placer gold, and have been washed for gold in several places. Thus far, however, the gold recovered has not been sufficient for profitable operation.

PLATE 26A

Asphalt Ridge

Green River is not an easy-going stream. Its respite in Ashley Valley is of short duration. A few miles southwest

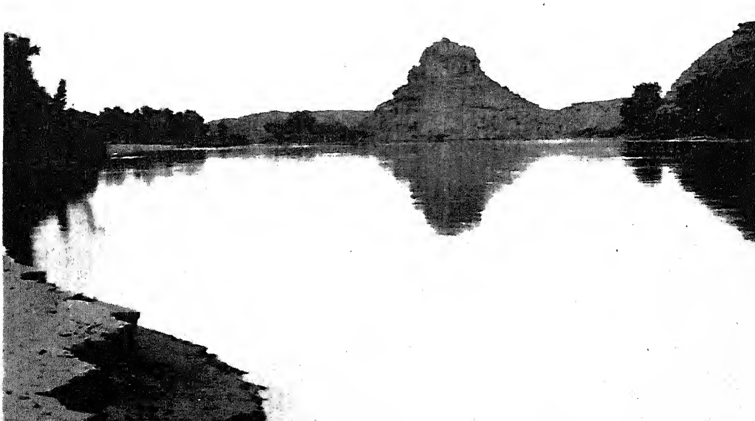
PLATE 25

A

B

PLATE 26

A



B

of Jensen it encounters a ridge composed of coal-bearing sandstone below and of sand, shale, and pebble beds above. The sandstone known to geologists as the Mesaverde formation contains thick beds of coal. The overlying rocks are Tertiary in age and contain deposits of asphalt, because of which fact it is known as Asphalt Ridge. Here the river flows between relatively low bluffs. But because of the nature of the rocks, the bluffs are practically vertical in many places. The beds of sand and mud from which these rocks were made were laid down in water in horizontal sheets, the layers of sand alternating with layers of mud. These beds have never been greatly disturbed. They lie practically as they were formed. The layers are jointed, that is there are many vertical cracks, and where the current undercuts the banks the rocks break along these cracks and fall away, thus leaving the bluff nearly vertical.

PLATE 26B

Scene in Wonsits Valley

At Asphalt Ridge Green River leaves the region of low, rounded bluffs and the rolling plain which developed on the homogeneous shale and enters a region of entirely different aspect. Here begin the rocks of Tertiary age, covering a large area. Over these rocks the Green flows for about seventy-five miles. The Tertiary beds fill the trough of the great depression called the Uinta Basin in which the older sedimentary rocks are bowed downward. At Asphalt Ridge the Cretaceous shale and sandstone of Ashley Valley disappear beneath the Tertiary rocks and reappear seventy-five to one hundred miles farther down stream in the vicinity of Book Cliffs. The still older rocks of the Uinta Mountain region also pass under the basin and reappear still farther to the south.

PLATE 27A

Entrance to Desolation Canyon

Below Ouray, Utah, a town situated at the mouth of Uinta River, the Green River enters an area of "badlands" which, judging from all that is known of them, seem to be bad in a variety of ways. Throughout this entire canyon the fall is rapid, the current swift, and the rapids numerous. The sides of the canyon are high terraced walls rising by broken and ragged vertical cliff and varied slope to heights possibly as great as three thousand feet. On the treads of the great steps in the terraced sides, some of them miles in width, stand buttes, and castellated forms of varied size and shape which are remnants of erosion left by the recession of the cliffs that now stand farther back from the river. The material which once filled the intervening space between the buttes was loosened by frost, washed down by rain, blown aside by wind and carried away by the river. After helping to excavate the canyons some of the material, together with similar material from other places, was deposited on the delta of the Colorado in southern Arizona and California, and some was carried out to sea.

PLATE 27B

River Bluffs near Head of Desolation Canyon

The course of the river in Wonsits Valley is somewhat winding. This so-called valley is about ninety miles long and broadens in some places until the confining bluffs are six to eight miles apart. The current is relatively slow and the river widens to six hundred or eight hundred feet.

South of Asphalt Ridge, Green River flows between bluffs having a distinctly angular aspect due to the occurrence of hard rocks in many layers, separated by beds of soft rock. The strata consist of sandstone and shale. Some

PLATE 27

A

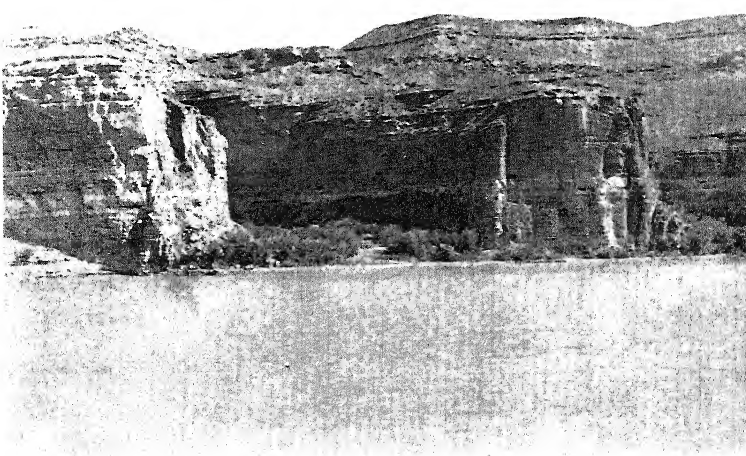


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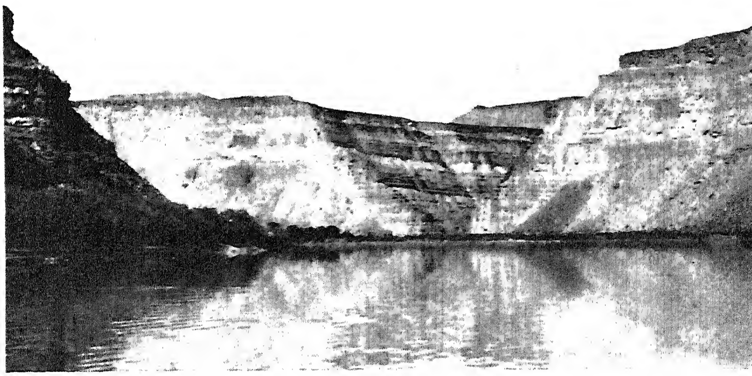
PLATE 28



A

B

of the rock is gray but much of it is colored in many shades of red, brown, green, and so forth. These are the Tertiary rocks that occupy the middle of a great structural trough called Uinta Basin which lies in western Colorado and eastern Utah south of the Uinta Mountains. These rocks in the middle of this down-warped region cover a belt about seventy-five miles wide, measured as the aviator flies. The coal-bearing sandstones of Cretaceous age which were seen north of Asphalt Ridge pass under the Tertiary beds in the middle of this basin and reappear at the surface again in Gray Canyon farther south. The older Cretaceous shale of Ashley Valley reappears at the surface to the south in Gunnison Valley.

PLATE 28A

Approaching the Mouth of Minnie Maud Creek

The bluffs in Desolation Canyon are relatively low at the north, but increase in height southward. The slightly inclined strata vary in hardness. When a stream cuts into rocks like these consisting of alternating layers of hard and soft rock, a series of shelves or steps is formed, each tread consisting of a hard layer of rock and each riser of softer rock. In this way were formed the terraced walls of the canyon shown on the opposite page. Some of the hard layers, more resistant than others, have been stripped of the softer material over a wide area, so that a plain is formed on the resistant layer. Such a plain is known as a stratum plain. Several of these occur in the sides of the canyon and on the plateau stretching back from the river.

PLATE 28B

Mouth of Minnie Maud Creek

Numerous tributary streams enter the Green in Desolation Canyon. Each one of these has cut a gorge of its

own, a miniature Canyon of Desolation. In many places where the tributary streams are close together they are separated by thin walls of rock hundreds of feet high. In some of these walls passageways have been broken through from one canyon to another. The rocks which span large passages having arched roofs are called natural bridges. Some of the smaller passages have been called "side doors between canyon chambers," others windows, portholes, and the like, descriptive of the particular aperture. The crags, pinnacles, natural monuments, castellated buttes, tower-shaped peaks and embossed walls make this region of desolation a curiously fascinating one, its weirdness enhanced by erratic weather conditions. Where the barren rock of the walls is exposed to the rays of the sun it is heated and strong up-currents of air are set in motion. On the other hand, the opposite effect is produced where the walls are shaded and cooled by radiation. The direction of the strong convection currents thus set in motion is influenced by the irregularities in the shape of the walls, by the tributary gorges, by the great amphitheaters, and by the smaller recesses. Hence the wind is gusty and changeable.

The layer of rock at the top of the wall juts out in some places like a cornice because, being harder than the rocks below, it has resisted erosion to a greater extent.

The work of the river and its tributaries in stripping the country and forming stratum plains, escarpments, and canyons and in producing buttes, cliffs, and the general aspect of desolation which gives this canyon its name, is shown more vividly by the accompanying sketch than by any combination of words.

The figure is reproduced from Major Powell's "Exploration of the Colorado River." The escarpment in the foreground represents the Orange Cliffs at the foot of Labyrinth Canyon, the second escarpment, the Book Cliffs at the foot of Gray Canyon, and the third, the Brown Cliffs at the foot of the Canyon of Desolation. The Jurassic sandstone of Orange Cliffs, the Cretaceous sandstone and shale of Book Cliffs, and the Tertiary beds of Brown Cliffs once extended continuously over the entire region illustrated.

Just as water, aided by chemical action, frost, and wind, sculptured the canyon walls shown in this Plate 28B, so the same sculptor aided by the same agencies, carved out the infinitely larger features, while the river carried to the sea the hundreds of cubic miles of rock chips produced in the process.

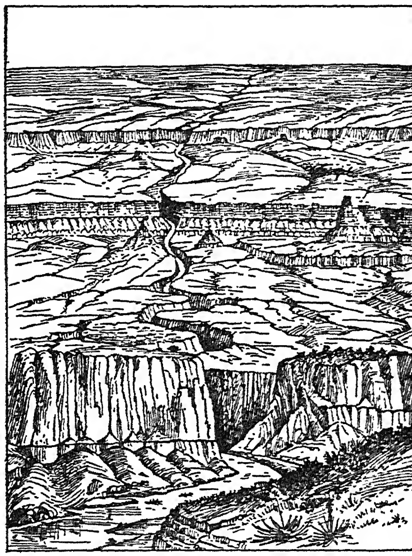


FIG. 4. Bird's-eye view of Terrace Canyons. (After Powell.)

PLATE 29A

DISSECTED WALLS

The cracked surface in the foreground results from the drying of mud under the heat of the sun. The next flood may fill these cracks with fresh mud and cover the whole mass with a new layer. Such masses of sediment subjected to the same processes that have acted in the already consolidated rocks would also solidify this into hard rock. In this way was formed some of the rock which now contains fossil mud cracks, rain prints, and the tracks of animals that crawled over the surface when the mud was soft.

Desolation Canyon takes its name from the desolate character of the region through which the river follows a tortuous course, between walls which are practically without vegetation. Their barren monotony is relieved in a few places by dwarfed thorny bushes rooted perhaps in a handful of soil and loose rock on some shelf, or clinging to the face of the cliff by means of a roothold in a crevice of the solid rock. These stunted shrubs have been aptly described as ugly clumps, like war clubs beset with spines. Large amphitheaters and smaller recesses in the walls in great variety of shape and size make a varied landscape.

PLATE 29B

In Lower Desolation Canyon

The strata of the walls of Desolation Canyon are yellow, gray, green, black, and red. Many shades are due to the blending of these colors. The bedding is regular. There is little evidence of faulting or folding, although the joint planes in the thicker strata are prominent. At one place a vein of gilsonite about twelve inches thick was found in a nearly vertical position. As gilsonite is a product of petroleum, this vein probably marks a passageway through which oil escaped from some rock reservoir below the surface.

The strata rise gradually to the south and southeast probably thirty feet to the mile. The sandstone varies in color from red to nearly white. The red bands contain iron oxide. Green copper stains, too, are much in evidence. These highly colored rocks are interspersed with bands of clay of duller shade from one to forty feet thick, making up a formation that grows more and more variegated and beautiful to the southward. As the different layers appear above the water they rise higher and higher and finally pass out at the tops of the hills. These barren hills show the color of each stratum. The iron-stained bands become darker and

PLATE 29

A

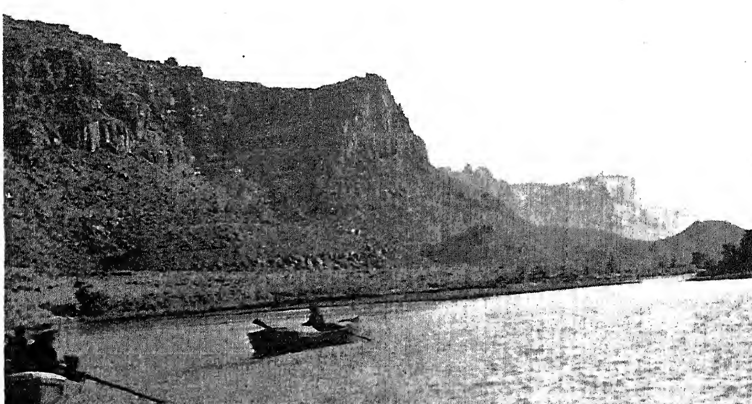


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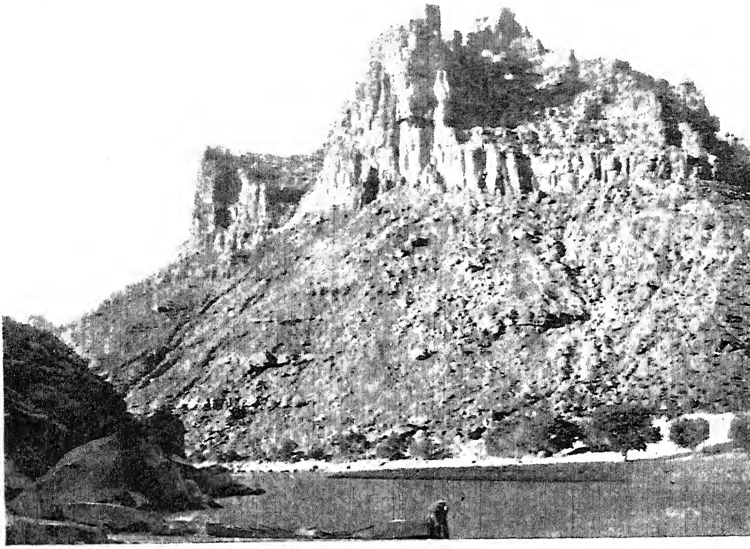
Plate 30



A

B

thicker to the south. Thin bands of light green sandstone come up, thicken and take on a deeper green. Then bands of yellowish green come in, while the dark red strata become streaked with green. Some of the iron-stained layers are eight to ten feet thick. The green are as much as four feet, but the yellowish green are not more than two feet. Thus the whole canyon wall is decorated in color, not as a painting on the surface, but as an inlaid mosaic which is perpetually renewed and brightened as the weathered surface wears away.

PLATE 30A

A Castle on the Green

Such castellated forms as that shown on the opposite page are common in Desolation Canyon and have attracted the attention of all who have visited the region. In his "Romance of the Colorado" Dellenbaugh describes an object on the top of a cliff which from the level of the river seemed the counterpart of a log cabin. Tall pines growing around it made the deception complete. The cliff being twenty-four hundred feet or so high, the "cabin" must in reality have been of huge size. Such remnants of erosion take on different shapes according to the kind of rock from which they are formed. A castellated butte such as this one would not be found in a region of massive granite, nor would it be carved in this form from steeply upturned strata. It is typical of the sculpturing produced by erosion in flat-lying beds of stratified rock.

PLATE 30B

Far from Home

Toward the southern end of Desolation Canyon, the nature of the rock changing, the canyon walls undergo a corresponding alteration. They become rugged and are

composed of strata of sandstone of varying hardness, interspersed with beds of red and green shale that are not very thick or persistent, coming in and pinching out in the most erratic manner. In some places there appear among them thin layers of a violet color and occasionally one of a pronounced purple. The cliffs near the south end of Desolation Canyon, rising two thousand feet above the river, are generally red and towering in the bright sun but seem to grow somber and mysterious as the shadows of night enfold them. The summits remain bright from the western rays long after objects in the depths near river level have become dim and uncertain. For one who has had experience with deep canyons, no description is needed to emphasize the weird effect of this blending of day and night. In such a strange setting the precipitous walls, the disorderly heaps of boulders, and the swirling, leaping waters of the rapids seem greatly exaggerated.

PLATE 31A

Sentinel Tower

At the southern end of Desolation Canyon, sentinel-like, stands the conspicuous landmark shown on the opposite page. The photograph shows the erosion as it appears from the open country south of the mouth of the canyon where the rocks of Tertiary age give place to the softer sandstones of Cretaceous age. During the stripping of the latter the Tertiary rocks of Roan or Brown Cliffs were eroded back to their present position, leaving Sentinel Tower as a reminder that these rocks once covered the country farther to the south. Such remnants are eloquent evidence of the former extent of the rocks composing them and are used to good advantage by geologists in determining the original extent of the rock formations.

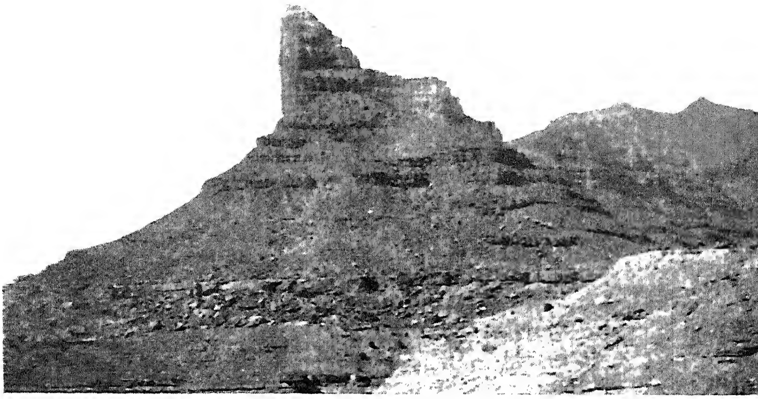


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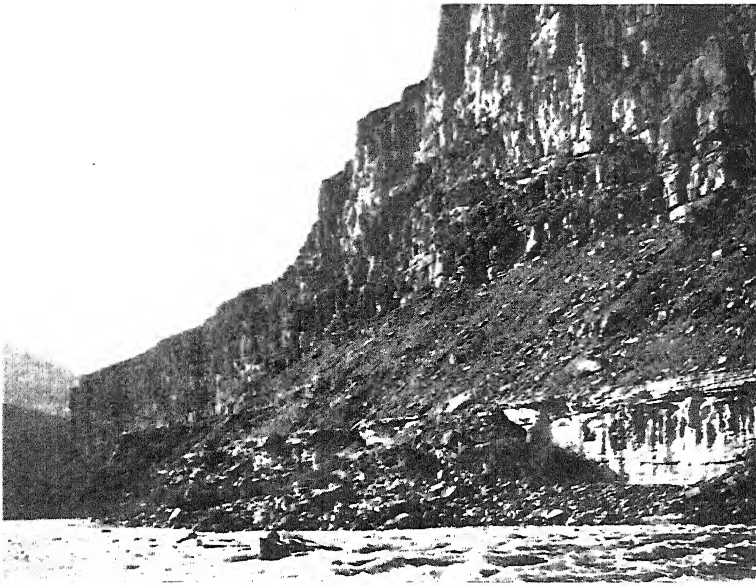
Plate 32



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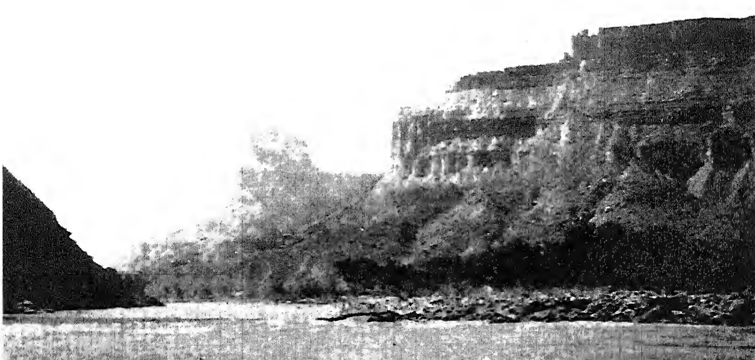

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PLATE 31B

North End of Gray Canyon

As one emerges from Desolation Canyon the aspect of the country changes abruptly. The river leaves the escarpment called Roan or Brown Cliffs. On emerging from the Tertiary rocks of these cliffs it passes through open country between low bluffs for a short distance, then cuts down into the gray sandstones of Cretaceous age known to geologists as the Mesaverde formation. These are the strata which disappeared from view north of Asphalt Ridge and extend underneath the filling of Uinta Basin. The Mesaverde is the great coal-bearing formation of Utah and western Colorado. Its coal is mined extensively in several places, but vast bodies of it are untouched and shall remain untouched until future generations need it. It has been estimated that in the Uinta Basin alone these rocks contain 167,682,000,000 tons of coal, within reach under present mining conditions, and probably many times that amount too deep to be mined at present.

PLATE 32A

Walls of Gray Canyon

Some of the layers of sandstone of the Mesaverde formation are very resistant and therefore form vertical cliffs. The streams which cross it cut deep, narrow canyons. Blocks of rock falling from their walls make rough water in the river. In Gray Canyon, the Price River enters the Green from the west. It is a stream of considerable size, draining an area of about 1,860 square miles. As this is a semi-arid region ranging in altitude from 4,200 feet to more than 10,000 feet, precipitation is variable, and the quantity of water supplied by this tributary river is irregular. Its average annual discharge is about 180,000 acre-feet, that is, the Price River contributes to the Green enough water in a

year to cover 180,000 acres one foot deep. Some of this water is used for irrigating land farther down stream, and still more of it will be used when projected irrigation works are completed.

PLATE 32B

Mouth of Gray Canyon

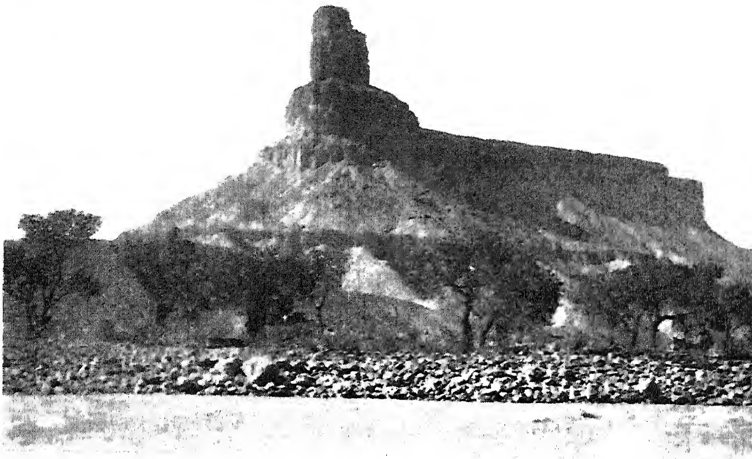
Like the strata in Desolation Canyon, those of Gray Canyon incline toward the north and rise in the canyon walls toward the south. Because of this rise of the strata, and because of the fall of the river in the same direction, the mouth of the canyon is soon reached. Here the Mesaverde sandstone ceases in a great escarpment called Book Cliffs and the river enters an open country where the Mancos shale (which was last seen in Ashley Valley one hundred miles farther north) comes again to the surface. The escarpment was called Book Cliffs because of a certain resemblance, fancied or otherwise, to rows of books which the cliffs present when viewed from a distance. The Mancos shale is so called because similar shale at Mancos, Colorado, supposed to be of the same geologic age, was named for that town.

PLATE 33A and B

Gunnison Butte

As the river emerges from the steep-walled gorge of Gray Canyon, it enters a region of soft rock which weathers into low, rounded hills. It is the thick mass known to geologists as Mancos shale, which accumulated as mud in the sea during the Cretaceous period. The ease with which this shale is eroded and the difficulty of eroding the more resistant sandstone above it causes the great escarpment which terminates Beckwith Plateau west of the river,

PLATE 33



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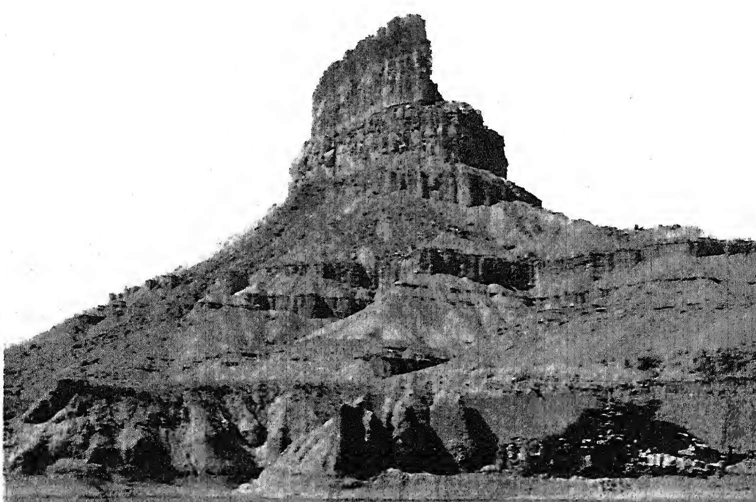

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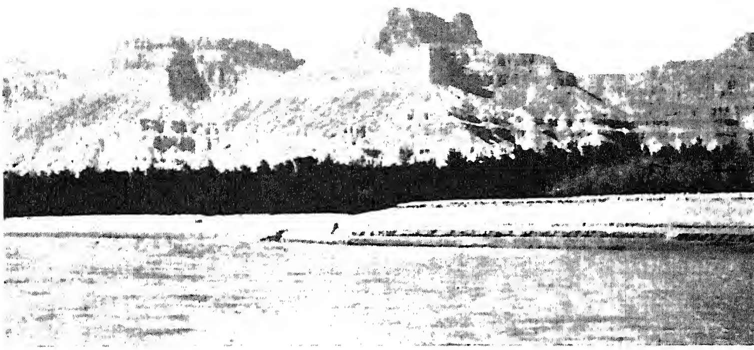
PLATE 34



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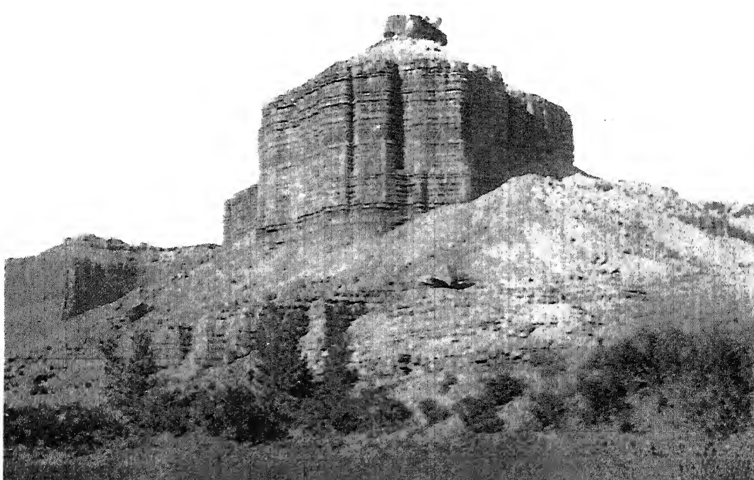


B

and the great escarpment of the Book Cliffs which extends far to the east. Just as Sentinel Tower is an outlying remnant of erosion of the Roan or Brown Cliffs, Gunnison Butte is an outstanding remnant of the Book Cliffs escarpment.

The upper photograph (A) is a view of the butte as seen at the end of the thin crest with the sparse growth of trees on the river bank and the usual line of boulders deposited by former floods. The lower photograph is a view of the side of the butte showing Mancos shale below and Mesaverde sandstone at the top. The vertical joints in this sandstone may be distinguished, and, having power of imagination equal to that of the original observers, one may be able to see here a resemblance to stacks of books.

The vertical joint planes showing in the lower right corner of Plate B are so smooth that they form a good reflecting surface, glistening in the morning sunlight.

PLATE 34A

Book Cliffs as Seen from Gunnison Valley

Gunnison Valley is an open part of the country south of Gunnison Butte in which the Denver and Rio Grande Western Railroad crosses Green River. The valley was named for Captain Gunnison, who, in the early days of Indian warfare, crossed the river here to his fate. Like Ashley Valley farther north, Gunnison Valley is a breathing place for the river after its strenuous endeavors in the canyons above. Here it flows serenely for a few miles before entering the still more troublesome canyons to the south. The beautiful green cottonwoods, the brilliant fields of alfalfa, and the fruit-laden orchards of this valley proved a grateful change to us who had just come through the barren stretches of the canyons above.

A mile or so below the railroad bridge the river leaves the shale of Gunnison Valley and enters a region occupied

by the McElmo formation over which it flows for about four miles, then cuts into a still older sandstone for a short distance. The McElmo consists of the variegated shale and gray to pink sandstone known elsewhere as the Morrison formation. This formation is seen farther up the river in Flaming Gorge and in Dinosaur National Monument. At an abrupt westward turn in the river a fault line crosses the course of the stream. Here the earth's crust was broken and the rocks south of the line slipped downward past those to the north of it. The extent of this displacement or down-slipping was more than seven hundred feet, for the Mancos shale which normally lies above the McElmo is let down to such an extent that in the river bluff it lies side by side with the sandstone which underlies the McElmo beds.

PLATE 34B

Dellenbaugh Butte or Anvil Rock

Dellenbaugh Butte, so named for F. S. Dellenbaugh, a member of Major Powell's second expedition, is situated about four miles north of the mouth of San Rafael River. It has roughly the form of an anvil and is locally known as Anvil Rock. Its peculiar laminated appearance is due to its composition. It consists of many thin layers of limestone, shale, and gypsum. These rocks are formed from sediments deposited in the sea water which flooded this part of North America in the latter part of the Jurassic period.

The rock formations exposed in the vicinity of Labyrinth Canyon are named in the following table in the order in which they lie, the younger at the top and the older below. At the left is indicated their geologic age and at the right their conspicuous characteristics.

Geologic Formations Exposed in and near Labyrinth Canyon

Age	*Formations and approximate thickness*	*Description*
Upper Cretaceous	Mancos shale 3000 feet thick	Dark colored clay shale, soft, eroded to low, rounded hills and barren slopes.
	Dakota sandstone 0–40	Sand and pebbles, loosely cemented.
	Unconformity	
Lower Cretaceous (?)	McElmo formation (Salt Wash sandstone member) 700 feet	Shale and sandstone vari-colored in lower part—Salt Wash member—consists of coarse sand and pebbles with dinosaur bones, petrified wood, and carnotite, uranium, and vanadium ore. The carnotite is mined for use in the manufacture of radium compounds.
Jurassic	Navajo sandstone 750 feet	Gypsum at top 15 feet thick. Colored-sandstone and shale; one massive sandstone 90 feet thick. Contains much quartz which weathers out as red balls or lozenges. Lower part chiefly reddish brown and yellow sandstone which makes conspicuous cliffs.
	Unconformity	
	Todilto (?) formation 100–300 feet	Limestone, sandstone, and shale with fossil shells of marine Jurassic invertebrates.
	Unconformity	
	Wingate sandstone (includes Gray Cliff, White Cliff, and Vermilion Cliff) 900 feet	Sandstone, massive, cross-bedded with pebble beds in some places, forms conspicuous red to gray cliffs such as The Ledge and Orange Cliff.
	Unconformity	
Triassic	Chinle formation 300 feet	Shale and sandstone, of many bright colors. Makes brilliantly colored slopes.
	Unconformity	
	Shinarump conglomerate 80–100 feet	Sandstone and pebble beds, containing fossil wood and radium-bearing ores. Makes cliffs and benches in the canyon walls.
	Unconformity	
	Moenkopi formation 350–600 feet	Sandstone and shale, red, appears beautifully laminated in the canyon walls and in faces of buttes.
	Unconformity	
Carboniferous	Kaibab limestone and older formations	Cherty limestone, sandstone, and shale.

PLATE 35A

SOUTH OF SAN RAFAEL RIVER

The San Rafael enters Green River from the west at the head of Labyrinth Canyon. It is a stream which supplies enough water to the Green each year on the average to cover 250,000 acres one foot deep. Below the mouth of the San Rafael the walls are high and precipitous because of the presence there of a thick massive sandstone, which has the habit of forming nearly vertical cliffs.

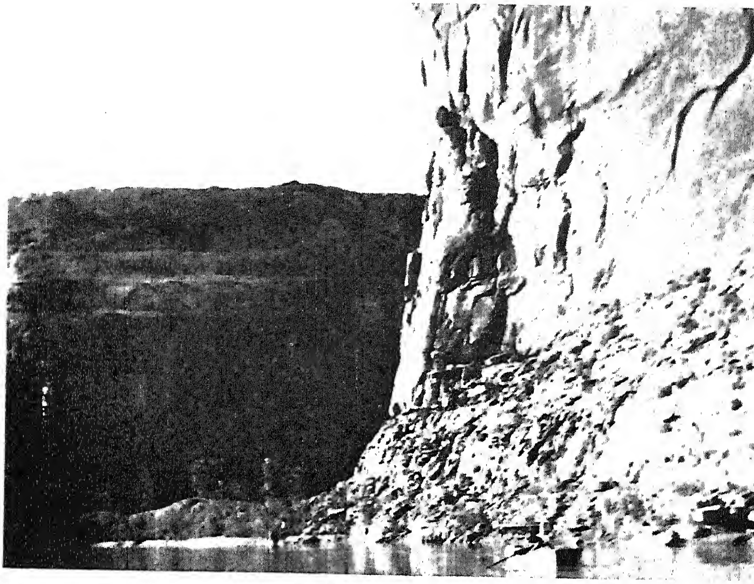
As this part of the country is semi-arid, many of the temporary stream courses do not have water in them frequently enough for effective cutting in the rock. While the river was rapidly lowering its course, these temporary streams were lowering their own very slowly, so that now they enter the canyon high in the walls. For this reason spectacular exhibitions are given during times of storm. During a rainstorm the accumulated rain water pours over the cliffs in muddy torrents. The whole country being barren and mostly solid rock, the rain gathers as from the roof of a house. Cascades fall with varying volume and color, some chocolate, some amber. Some fall several hundred feet, vanishing in spray and presenting varied, exquisite effects in combination with the rich tones of the wet brown sandstone and the background of dark gray sky. The cascades continue for a time after the rain has ceased, and then vanish as though the flood-gates had been closed.

PLATE 35B

CANYONS AT TRIN-ALCOVE BEND

At Trin-alcove Bend three small side canyons open into Labyrinth Canyon so close together that they appear as three alcoves. In the central one we pass between high walls of sandstone and wind about in glens. There are many side canyons. The right cove is a narrow, winding gorge with overhanging walls. The left is an amphitheater turn-

Plate 35



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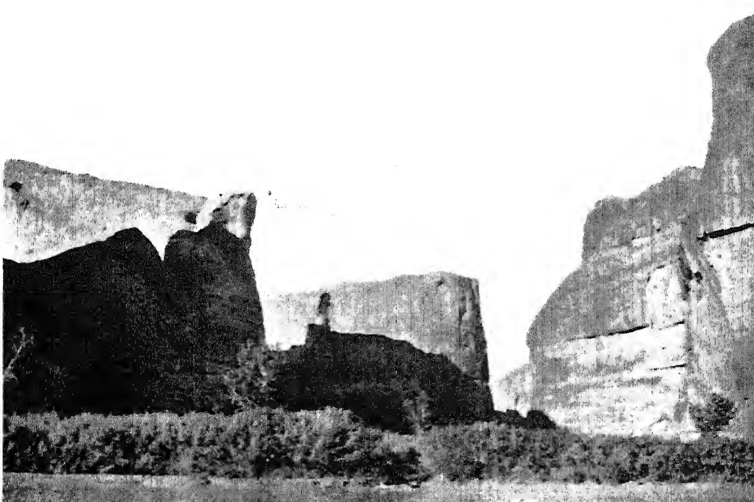


B

PLATE 36

A

B

ing spirally up, with overhanging shelves. Huge rocks are piled below on the right. This stratum is the Wingate sandstone which is conspicuous south of the mouth of San Rafael River, and for many miles is the canyon-making rock.

PLATE 36A

Wingate or Vermilion Cliff Sandstone

The Wingate sandstone includes the rocks which the older geologists called Vermilion Cliff and White Cliff (or Gray Cliff) sandstone. It has a thickness of probably nine hundred feet in Labyrinth Canyon, but is much thicker than this in many other places. This sandstone contains fossil sand dunes, comprising the sand accumulations of a great American Sahara which existed in the early part of the Jurassic period, long before the earth was habitable of man. The quantity of wind-blown sand in this formation is an eloquent reminder of the great length of time that the desert endured, for it reaches from Arizona northward into Wyoming and Idaho, and from central Utah, where it is about three thousand feet thick, to central Colorado, where it thins out.

This sandstone is the cause of remarkable landscapes wherever it occurs at the surface. A scene near this locality is described as follows: "In every direction, as far as we are able to see, naked rocks appear. Buttes are scattered on the landscape, here rounded into cones, there buttressed, columned, and carved in quaint shapes, with deep alcoves and sunken recesses. All about us are basins, excavated in the soft sandstone, and these have been filled by the late rains. These rain-filled basins, commonly called water-pockets, are of great practical use in the semi-arid West, for over wide areas of country they are the only source of water during long rainless periods."

PLATE 36B

Sandstone Butte North of Bowknot Bend

Captain C. E. Dutton, who examined a large part of the plateau country, describes the massive sandstone formation here exposed as one strangely marked by lithological characteristics. Quite as strangely individualized are the topographical features which rain and frost have carved from it. The great marvels of surface sculpture, the grand cliffs with strange carvings and elaborate ornamentations, the wonderful buttes and towering domes, the numberless forms which startle us by their grotesqueness, all these owe their peculiarities as much to the nature of the rocks themselves as to the abnormal meteorological conditions under which they were produced. The upper part of this sandstone commonly known as White Cliffs sandstone is wonderful for its cross-bedding, for the massiveness and homogeneity of its stratification, and for its persistence without any notable change of character over great areas.

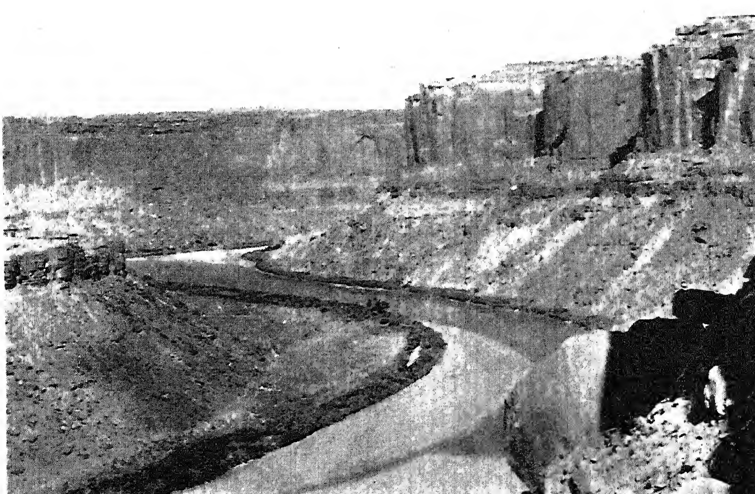
The mesas of the plateau country in general are illustrated in the region which lies between the canyon and the distant escarpment. Here low tablelands, dry and treeless, stretch back from the brink of the canyon, usually showing smooth surfaces of naked, solid rock. In some places where the country rock is composed of marls the surface is a bed of loose disintegrated material, in which one walks "as in a bed of ashes." Often these marls are richly colored and variegated. In other places the country rock is a soft sandstone, the disintegration of which has left broad stretches of drifting sand.

PLATE 37A and B

Canyon Wall North of Bowknot Bend

The course of the river below the mouth of the San Rafael River is tortuous, and near Bowknot Bend it nearly doubles upon itself. The water is here quiet, so that constant

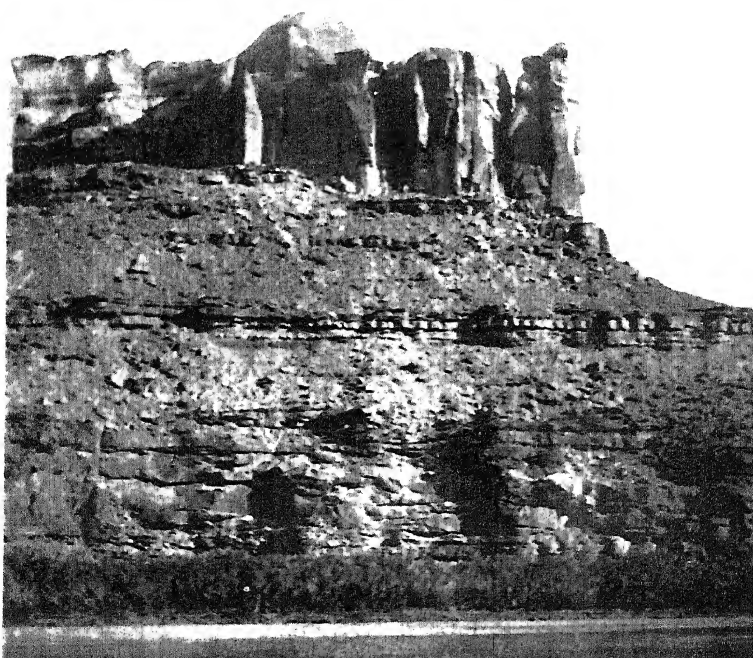
A



B

PLATE 38

A



B

rowing was necessary to make headway. In some places there is a narrow flood plain between the river and the wall, usually on the inner side of a bend. Where long, gentle curves are found the river washes the foot of the outer wall. Long peninsulas of willow-bordered meadow project within the curves and the talus at the foot of the cliffs is usually covered with dwarf oaks and willows. The orange-colored sandstone which forms the cliff rising above the talus is very homogeneous in structure. The walls are usually vertical, though not very high. Where the river sweeps around a curve with sufficient force to undercut the cliff, a hollow dome may be seen, with caves and deep alcoves. The whole region is carved intricately, marvelously. There are scores, hundreds, multitudes of all shapes and sizes, any one of which if situated elsewhere might be exploited as a natural wonder.

PLATE 38A

Bowknot Bend

Bowknot Bend is a beautiful example of an entrenched meander. The river makes a sharp turn to the west, then doubles back in a circuit of three and one-half miles and approaches within half a mile of its first turn. Then after a circuit of seven and one-half miles to the eastward, it returns to within a few hundred feet of its former course at the point shown in the photograph on the opposite page.

The rocks of the walls in this bend and for a considerable distance to the south are Wingate or Vermilion Cliff sandstone above, and Chinle formation below. The Chinle formation consists of shale and sandstone of many colors including red, yellow, brown, dove, mauve, and lavender. The beds are relatively soft and form step-like slopes leading up to the foot of the great wall of Vermilion Cliff sandstone above. It is the Chinle formation that contains the stone logs of several of the petrified forests of the southwest, and, because of its bright colors, helps to make brilliant landscapes throughout the plateau region.

The course of the river is known technically as antecedent and superimposed. It was developed long ago before the surface attained its present altitude. The winding course (established probably when the river was flowing over a graded plain) which once stretched across the site of the canyon became fixed when the stream cut down intc the hard rock.

PLATE 38B

At the Neck of Bowknot Bend

The river is tranquil in this part of its course, and the smooth surface of the evenly flowing current contrasts sharply with the turmoil of the waters in other parts of its course. Powell refers to the "exquisite charm" of his ride down this beautiful canyon which gradually grew deeper with every mile of travel. The walls are symmetrically curved, grandly arched, beautifully colored.

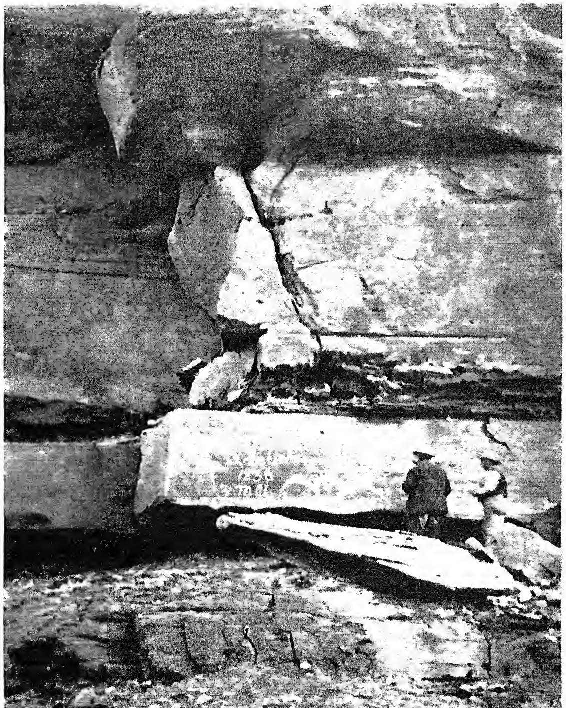
Labyrinth Canyon was named for its elaborately winding course as well as for its wonderfully intricate system of dry lateral canyons, the present rock shapes resembling castles, arches, grottoes, and other architectural forms. Here, as in hundreds of other places along the river, the walls are strangely carved into a variety of buttes and amphitheaters, monuments and caverns, hillocks and water holes. From below, the view is one of walls and pinnacles. From above a remarkable panorama opens to view. Buttes and gorges appear on all sides with the river so completely lost in the abruptness of its chasm that, viewed from a point a mile from the brink, the whole region seems solid, and the existence of the gorge with a river at the bottom is not even suspected.

PLATE 39A

Near View of the Massive Red Sandstone

Labyrinth Canyon is barren but not monotonous. It is varied in color, being red at midday, orange-tinted at sun-

Plate 39



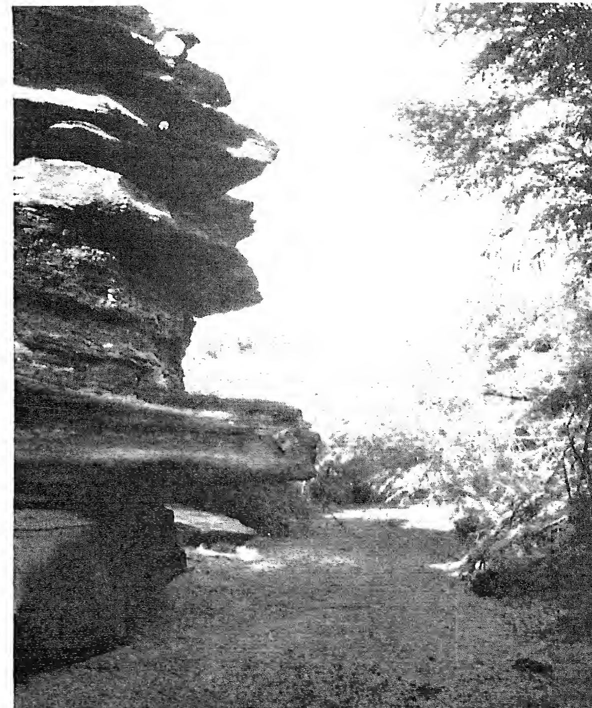
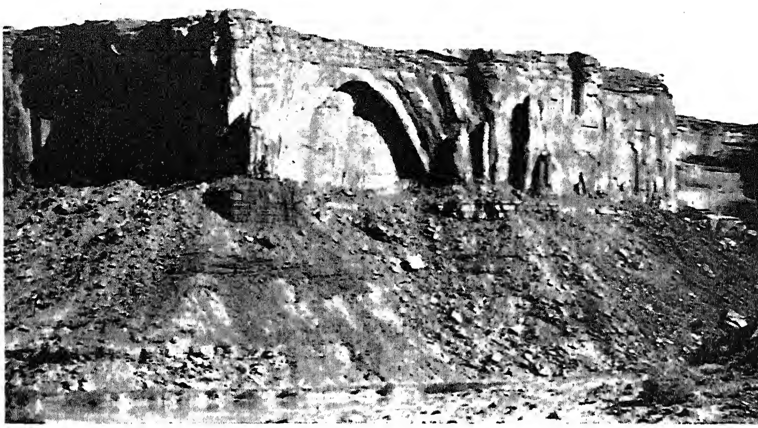


PLATE 40



A

B

set, with the gauze-like purple shadows and delicate blue outlines characteristic of the western distances. On close examination the canyon walls are found to be made up, not of a single bed of sandstone, but of many thick layers of sand separated by thin layers of less massive shaly sand which weathers more readily than the material of the massive beds. Such smooth faces of rock have tempted artists of all ages and climes. They are particularly tempting to the omnipresent advertising agent and to the practical joker who delights in trying to deceive the ethnologist who "discovers" his crude imitations of ancient symbols. The inscription found on the south wall of Hell Roaring Canyon has interested many people because of the date. Little is known of D. Julien except that similar inscriptions are found both up stream and down stream and are believed to be genuine. It is well known that trappers and hunters visited the river long before the canyons were systematically explored. Possibly D. Julien was one of these.

PLATE 39B

Mouth of Hell Roaring Canyon

A few miles below Bowknot Bend a tributary entering the Green from the east has cut through the massive red sandstone a sharp gorge known by the expressive name of Hell Roaring Canyon. At ordinary times the roar is not terrifying. But the undercut rocks and their water-polished surfaces are mute reminders that there are times when the canyon has not the peaceful aspect shown in the photograph on Plate 39B. During storms such gorges hold roaring torrents of muddy water sweeping in terrifying fury down their rock-ribbed troughs. These are fed by the rain-born cascades which plunge over the brink from the rock shelves above where they have gathered chocolate, amber, and red sand and boulders. The rocky walls, mainly of purplish-red tint, are so nearly perpendicular that in some places the cascades fall clear without a break. The rills and

rivulets rapidly unite to form veritable floods which then seek the river. This part of the river's course is curious as well as fascinating. It is a fantastic region of buttes, pinnacles, turrets, spires, castles, gulches, alcoves, canyons, and still more canyons, all hewn "as the years of eternity roll" out of a verdureless labyrinth of solid rock. It seems like a forbidden realm, with scenes unreal and apart from those of actual experience—a realm of fantastic dreams.

PLATE 40A

The Beginning of a Natural Bridge

The canyon walls in the southern part of Labyrinth Canyon are particularly imposing. The strata rise toward the south, so that the softer beds which occur below the cliff-making sandstone crop out between the river and the foot of the great sandstone cliff. These softer beds give way in some places, weakening the support and allowing parts of the sandstone in the face of the cliff to drop out of place, leaving hollows called natural panels or blind windows. If for any reason such as the sapping of the wall by a spring where the rocks are weakened by constant wetting, the rock under the arch continues to crumble, the blind window may be broken through and a passageway made into some tributary gulch through a real window or underneath a natural bridge. Natural bridges are formed in other ways under certain conditions, but in the massive sandstone formations of the canyon region, great numbers of them are formed by the sapping of the cliffs and the fall of rock from beneath arches.

PLATE 40B

Massive Walls of Labyrinth Canyon

In the same way that blind windows and natural bridges may be formed where the weaker beds below the sandstone give way, a general escarpment at the top of the canyon walls is formed. The rock below the massive sandstone consists of many layers of relatively soft red sandstone and shale. A few of the individual layers have a thickness exceeding two hundred feet. Some are beautifully cross-bedded and although this feature is not so strongly marked as in the more massive sandstone above, it is conspicuous enough to attract attention. The whole formation is brilliantly colored, the predominating hue being a bright, lively red, often inclining to orange. These softer beds form ragged general slopes in the lower parts of the walls, made up of many steps and minor slopes formed on the alternating hard and soft strata.

PLATE 41A

A Tower in Tower Park

The photograph shows a characteristic remnant of erosion in Tower Park. A small part of the sandstone of Orange Cliffs still remains at the top. The rocks under this sandstone are the softer, less massive red beds of Triassic age. The evenly laminated rocks at the foot of the wall indicate a recently formed cliff which has been kept free from slide rock by the river sweeping away the loose material as it fell from the solid masses above. All who have visited this region speak of thousands of buttes and pinnacles, suggesting immense towers, temples, cathedrals, and almost anything the imagination pictures. Much has been said of the Butte of the Cross. This consists of a flat-topped mesa and a tower which, rising in front, appears to be higher than the mesa and seems to be a part of it when viewed in

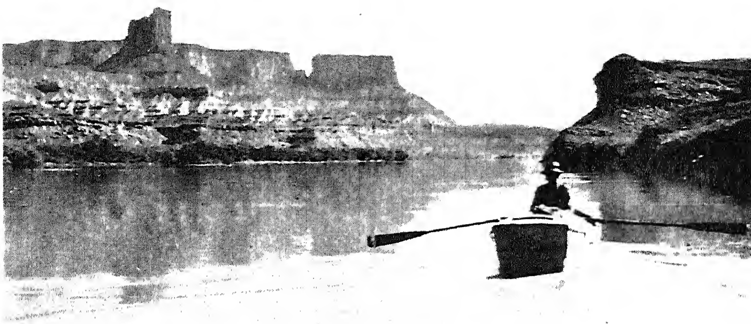
a certain direction, but which in reality is entirely separate from it. It is not strange that those who saw this country for the first time should wax enthusiastic over such an impressive exhibit of natural wonders. Major Powell speaks of the region as "a whole land of naked rock with giant forms carved on it; cathedral-shaped buttes towering hundreds or thousands of feet; cliffs that cannot be scaled, and canyon walls that shrink the river into insignificance, with vast hollow domes, tall pinnacles, and shafts set on the verge overhead, and all highly colored—buff, gray, red, brown, and chocolate; never lichened; never moss-covered; but bare, and often polished."

PLATE 41B

A Butte in Tower Park

Buttes and mesas are remnants left by erosion from layers of rock which once extended continuously over the region now occupied by these remnants. In Tower Park the Green River first cut through the massive sandstone of the Orange Cliffs into the soft rocks below and formed the narrow gorge of Labyrinth Canyon. As the walls were eroded, this hard sandstone maintained a nearly vertical face or cliff of erosion. As erosion continued, the cliffs were pushed farther and farther back as an escarpment of recession. During this recession of the cliffs, gulches formed in the re-entrant angles, and their branches in some instances coalesced, cutting off the salients from the cliffs. As the escarpment receded, some of the isolated parts which escaped destruction remained as outliers. The large, flat-topped outliers are known as mesas, the small flat-topped ones, like that shown in the photograph opposite, as buttes, and the still smaller, pointed remnants as monuments.

PLATE 41



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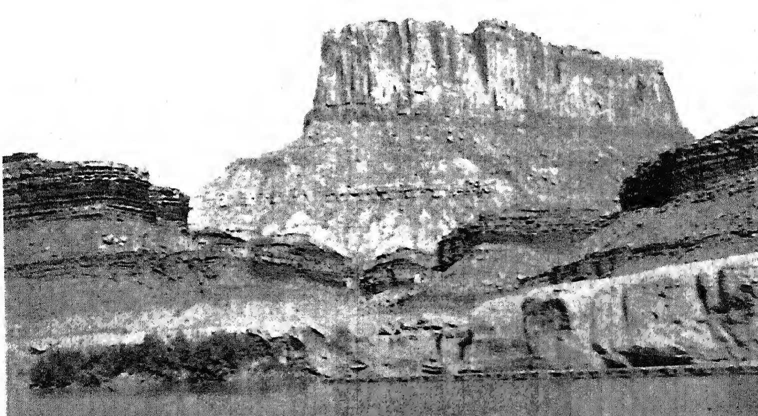

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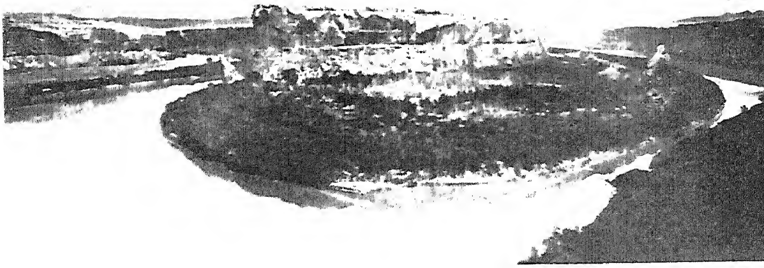
PLATE 42



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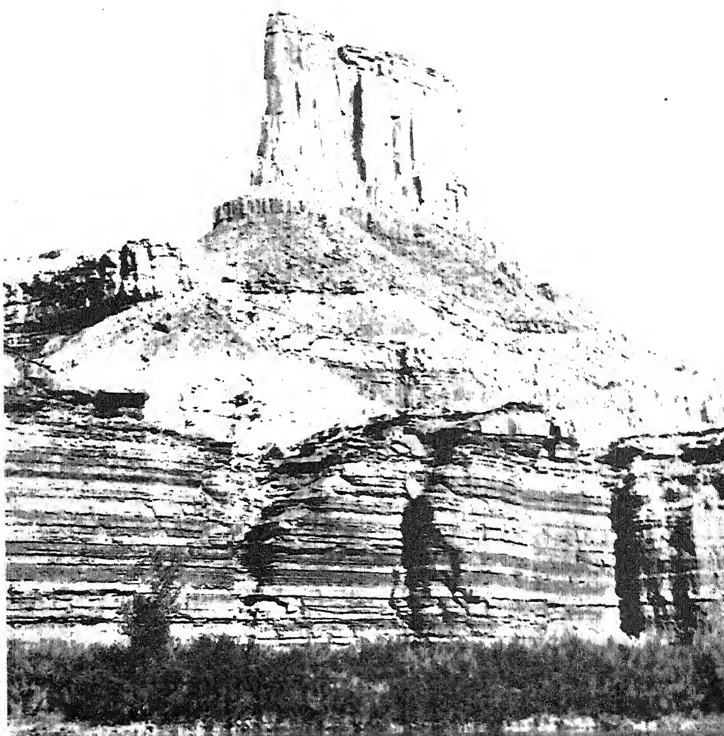

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PLATE 42A

Bonito Bend—an Abandoned Meander

This bend in the river marks the end of Labyrinth Canyon and the beginning of Stillwater Canyon, which is next in order to the south. It is a place where two bends of the river came so close together that the intervening rock was worn away and a new channel formed, by which the river avoided a long journey around. The old channel ran in a great circle around to the right by what was first a circular peninsula, then an island. When the short cut was formed the water left the old channel entirely, and this part of the old course of the river is now dry. So the great circular rock stands by itself, with precipitous walls all about it. There are few places where it can be scaled. Looking from its summit one sees a long stretch of river, sweeping close to the overhanging cliffs on the right, but having a little meadow between it and the wall on the left. In the photograph on the opposite page some of the characteristic buttes of Tower Park appear in the distance. The Butte of the Cross may be distinguished at the right.

PLATE 42B

In Tower Park

Here the escarpments of massive sandstone swing apart and away from the river and form the Orange Cliffs. This escarpment is one of the remarkable scenic features of the canyon country. In Tower Park many erosion remnants of the sandstone of the Orange Cliffs remain in the form of buttes, mesas, and natural monuments as evidence that the Orange sandstone once extended continuously over the area surrounding the buttes. The Indians called this the "Toom-pin Tu-weap," or Rock Land, and sometimes "Toom-pin Wu-near Tu-weap," or Land of Standing Rocks. The landscape away from the river is made up of rock in the form

of cliffs, tables of rock, terraces of rock, crags of rock—thousands of strangely and curiously carved rock forms everywhere, but no soil and no vegetation. In long, gentle curves the river, strongly entrenched deep in its rocky gorges, winds in and out among the varied elements of this wonderland.

PLATE 43A

A Scarp-making Layer of Rock

Below Bonito Bend the massive sandstone that caps the buttes and rims the walls in Labyrinth Canyon ceases as a maker of canyons. It is eroded away from areas farther south except where it still caps isolated buttes. This sandstone forms the rim of the Orange Cliffs, which stand well back from the river. From a distance their glory is appreciated as it cannot be when seen from points near by. These cliffs constitute one of the great escarpments which are never-ending sources of wonder to those who know them. After the canyons probably the most remarkable features of the canyon country are the long lines of cliffs. These are bold escarpments, rising hundreds, sometimes thousands, of feet above the plain below. They are great geographic steps, gigantic stairways, scores or hundreds of miles in length, presenting steep faces of rock, often nearly vertical. Having climbed one of these steps, one may descend by a gentle, sometimes imperceptible slope to the foot of another equally imposing escarpment. They thus present a series of terraces, the steps of which are well-defined escarpments of rock. The lateral extension of the cliffs is usually irregular. Many sharp salients are projected on the plains below, and many deep recesses are cut into the terraces above.

The rise of the strata toward the south and the fall of the river in the same direction bring the Vermilion Cliff sandstone to a position high in the walls in the lower part of

Stillwater Canyon. Below this sandstone the older red beds crop out, and finally, where the Green enters the Colorado River, rocks of Carboniferous age appear in the walls. The Vermilion Cliff sandstone forms steep-faced escarpments like that of the Orange Cliffs, rising probably thirteen hundred feet above the river. This sandstone makes cliffs which are difficult to climb, and surfaces which render travel over them laborious, yet strangely interesting. Major Powell records that in a journey from the canyon to the Orange Cliffs he wandered in deep, painted alcoves and over terraces paved with jasper. This language of Revelations does not prove that he was thinking of the "jasper walls" of another realm, for other observers have found in the red beds of this region layers containing much silica in a form usually called chert but sometimes referred to as jasper. This hard material accumulates on the surface, while the softer rock containing it is eroded away. From the top of the canyon wall "an astonishing cyclorama" is revealed. Men who have viewed this scene say that nothing is in sight but barren sandstone, red, yellow, brown and gray, carved into an amazing multitude of towers, buttes, sheer pinnacles, some of them several hundred feet high, and all shimmering in the dazzling sunlight. The barren rock is slashed in all directions by crevices; "crevices wide, crevices narrow, crevices medium." Scarcely can the traveler go a hundred yards without being compelled to leap some deep, dark gash.

PLATE 43B

Upper Strata Near Mouth of Green River

The Kolb brothers ("Through the Grand Canyon from Wyoming to Mexico") state that while a climb to the top of the canyon wall entails much labor, it brings rich reward in the form of unusual experiences and thrilling scenes. Some place may be found where a narrow gulch is cut through the wall of the main canyon. Following this up, the climb is rapid, as if one were going up a mountainside. The gulch may lead but a few hundred or a few thousand

feet from the river, but it has its side gulches and as the surface of the plateau is approached, small radiating canyons lead to the top. The spaces drained by these little canyons are terraced and a varied assortment of amphitheater-like hollows are to be found. Usually the spaces drained by any two of these little side canyons are separated by a narrow wall, one hundred, two hundred, or three hundred feet high, and often only a few feet thick. Sometimes the wall is broken into a line of pyramids above, which remain joined by a wall below. There are a number of these gulches which break the wall of the main canyon of the Green, each one having its system of side canyons and amphitheaters enclosed by walls or lines of pinnacles.

PLATE 44A

Junction of the Green and the Colorado Rivers

At this point shown in the photograph on Plate 44A between walls more than one thousand feet high, the waters of the Green River mingle with those formerly called the Grand. But as the Green here loses its identity, so also does the Grand, though in a different way. By act of Congress, the Grand will hereafter constitute the upper part of the Colorado River. By this act, approved July 25, 1921, "the river heretofore known as the Grand River, from its source in the Rocky Mountain National Park in Colorado, to the point where it joins the Green River, in the state of Utah and forms the Colorado River, shall be known and designated on the public records as the Colorado River." This river rises to the eastward among the impressive peaks of the Rocky Mountains where it drains numerous emerald lakes held like gems high amid the glacial crags. The upper Colorado (Grand River) drains about 25,900 square miles of country, ranging in altitude from 3,900 feet to more than 14,000 feet, and as it heads in the high mountains of Colorado, it carries great volumes of water in spring and early summer when the snow is melting, and lesser volumes at other seasons. Its annual discharge at its junction with the

PLATE 43

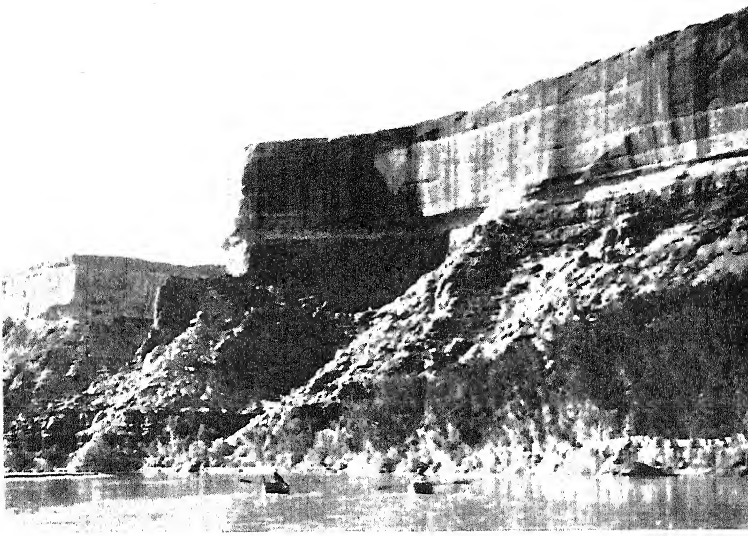

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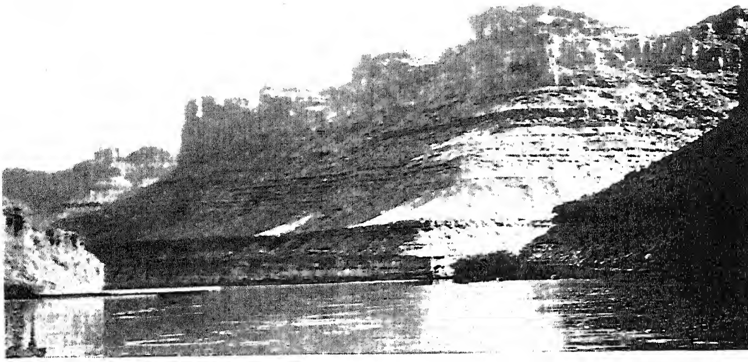
PLATE 44



A

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Green is about 6,720,000 acre-feet. That is, it would flood in a year about 10,500 square miles to the depth of one foot.

The scene near the mouth of the Green River, both in the canyon and from the top of the walls, is varied, impressive, and commanding. Some day, perhaps, surfeited globe-trotters, after having tired of the commonplace scenery and flabby diversions in foreign lands, will learn what a wonderful region here awaits them.

PLATE 44B—A Scene at the Rim

In the photograph opposite is presented one of the many interesting bits of landscape which greet the hardy climber who mounts the thousand-foot walls near the mouth of the Green River. The character of the view seems in keeping with the difficulty experienced in obtaining it. The scene is one of naked rock, the only signs of life being a few stunted shrubs. Here is nothing restful, nothing of the mellow loveliness which characterizes the ordinary landscape. The scene is hard, weird, and fascinating in its strangeness. It stimulates the observer in a strange way. He is tempted to exertion beyond his strength. He must needs see what is beyond, and then what is still beyond, until his strength is gone.

There is a matter of quite different interest connected with this photograph and the few others used in this volume which were taken on Powell's exploring expedition. In place of the marvelously convenient and efficient film-using cameras of the present time, these explorers were provided with the cumbersome apparatus for taking photographs on wet plates. To obtain the picture on the opposite page the heavy, clumsy apparatus was hoisted from ledge to ledge, pulled up slopes, pushed up through crevices in the rock, "worried" up a thousand feet to the top where the exposure was made, and then "worried" down again. But the results obtained by means of this crude outfit on an expedition such as that conducted by Major Powell constitute one of the marvelous achievements in early landscape photography.

This photograph was taken by Hillers.

PLATE 45A

Canyon Wall at the Confluence From Below the Mouth of the Green River

Past the point shown in the photograph opposite go the waters of streams born in cold, lofty solitudes which have an eventful history on their way through strange gorges and wonderfully colored canyons. These waters tumble in unnumbered cascades and cataracts, swirl through uncounted whirlpools, dance over many a rapid, to reach at last the parched plains of Arizona and Southern California. At this point the waters of the Green, which have their source far to the north in the eternal snows of the Wind River Mountains, mingle with those of the Grand, or, to conform to the recent act of Congress, with those of the Colorado River, having their source in the snow-capped Rocky Mountains of Colorado. The Green contributes to the Colorado the drainage from about 44,400 square miles of country, or enough each year to cover about 8,700 square miles with water one foot deep. By its never-ending succession of floods originating in these high mountains and bearing seaward the loads of silt and sand, gravel and boulders, the river has cut down through the rocks so rapidly that little has been done toward widening the canyon. The walls are too steep for much loose rock to lodge on them, and so close to the river that the rock waste is swept away as fast as it is formed.

PLATE 45B

Below the Mouth of the Green

Cataract Canyon begins at the mouth of the Green River and is cut in the hard rocks of Carboniferous age. The overlying red rocks of Triassic and Jurassic age have been eroded away in part or in whole near the brink of the gorge. Between the canyon and the distant cliffs are the strangely carved and pinnacled rocks of the Toom-pin Wu-near Tu-

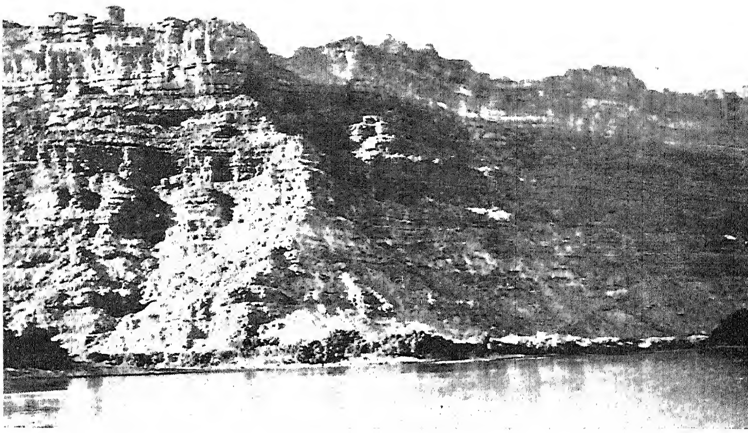

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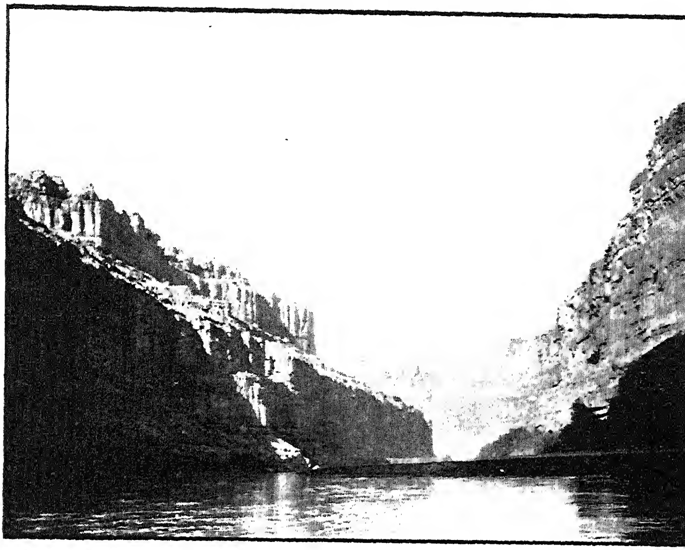
Plate 46



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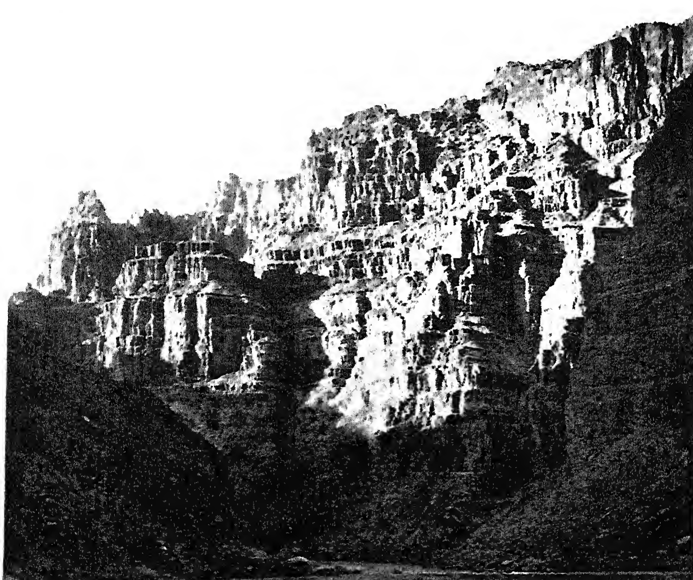

B

weap (Land of Standing Rocks). Far to the east a group of eruptive mountains may be seen—the Sierra La Sal. Their slopes are covered with pine trees and the deep gulches in their sides are flanked with great crags. Snow fields lie near the summits. "So the mountains are in uniform of green, gray, and silver." Between the river and the mountains is a wilderness of rock. There are deep gorges where rivers are lost among cliffs. There are towers and pinnacles, and thousands of strangely carved forms in every direction. Through scenes such as this the Colorado takes its eventful course, cutting, grinding, forcing its way through all difficulties. Here begins the turbulence of Cataract Canyon and the troublesome descent over heaps of boulders and through the swirling water of rapids that make the name Cataract eminently appropriate for this canyon.

PLATE 46A

In Upper Cataract Canyon

The Colorado River below the mouth of the Green is confined between precipitous walls of barren rock, and the swift, turbulent current is beset with numerous rapids. "Ten million cascade brooks unite to form ten thousand torrent creeks; ten thousand torrent creeks unite to form a hundred rivers beset with cataracts; a hundred roaring rivers unite to form the Colorado, which rolls, a mad, turbid stream, into the Gulf of California." According to observers who have climbed the walls west of the river, the country back from the rim is as wild as the river below, a barren, rock-strewn land, broken up by deep crevices. Between the crevices the surface is naked sandstone, without vegetation except for an occasional dwarf cedar or a piñon pine which has found a footing in some crack of the rock. There are great stone basins holding rain water—some only a few gallons, others hundreds of barrels. The semi-arid climate and the character of the rocks conspire to make the surface of the country in the vicinity of Cataract Canyon bleak and forbidding.

PLATE 46B

A Possible Reservoir on the Colorado

The steep walls of hard rock in the narrow gorge below the mouth of the Green River have proved tempting to engineers who are interested in controlling the flow of the river for purposes of irrigation and for the production of power. The walls here present barren faces of hard rock, the more resistant layers standing out as shelves.

PLATE 47A

Why the Canyon Was Named Cataract

Rough water is encountered almost immediately as one enters the canyon and throughout its length of forty-one miles as measured on the river, it is characterized by difficult water. In this distance the river descends about four hundred feet. Over innumerable heaps of broken rock the waters boom and plunge in a mad, irresistible flood.

A significant commentary on the nature of these rapids is found in Major Powell's account of an impromptu conference held in Cataract Canyon. His assistants, who had already overcome great difficulties, fell to discussing the probabilities of successfully navigating the river below. "There are great descents yet to be made, and if they are distributed in rapids and short falls as they have been heretofore, we will be able to overcome them. But maybe we shall come to a fall in these canyons which we cannot pass, where the walls rise from the water's edge so that we cannot land, and where the water is so swift that we cannot return. Such places have been found, except that the falls were not so great but that we could run them in safety. How will it be in the future; so they speculate over the serious probabilities." It is, however, pertinent to state in connection with the above quotation that Powell *knew* the waters of the Colorado were always muddy, and that this fact was the best possible evidence that no vertical falls would be found, because no such phenomenon exists or can exist in a muddy river.

PLATE 47B

Difficult Scaling the Walls in Cataract Canyon

The difficulties experienced among the rocks of the canyon walls cannot be indicated better than by quoting one who has had that experience. Major Powell says, "Climbing for

an hour over and among the rocks, we find ourselves in a vast amphitheater, and our way cut off. We clamber around to the left for half an hour, until we find that we cannot go up in that direction. Then we try the rocks around to the right, and discover a narrow shelf, nearly half a mile long. In some places this is so wide that we pass along with ease; in others, it is so narrow and sloping that we are compelled to lie down and crawl. We can look over the edge of the shelf, down eight hundred feet, and see the river rolling and plunging among the rocks. Looking up five hundred feet, to the brink of the cliff, it seems to blend with the sky. We continue along until we come to a point where the wall is again broken down. Up we climb. On the right, there is a narrow mural point of rocks, extending toward the river, two or three hundred feet high, and six or eight hundred feet long. We come back to where this sets in, and find it cut off from the main wall by a great crevice. Into this we pass. And now a long narrow rock is between us and the river. The rock itself is split longitudinally and transversely; and the rains on the surface above have run down through the crevices, gathered into channels below and then run off into the river. The crevices are usually narrow above, and by erosion of the streams, wider below, forming a network of caves; but each cave having a narrow, winding skylight up through the rocks. We wander among these corridors for an hour or two, but find no place where the rocks are broken down, so that we can climb up. At last we determine to attempt a passage by a crevice, and select one we think wide enough to admit of the passage of our bodies, and yet narrow enough to climb out by pressing our hands and feet against the walls. So we climb as men would out of a well. Bradley climbs first; I hand him the barometer, and then climb over his head, and he hands me the barometer. So we pass each other alternately, until we emerge from the fissure, out on the summit of the rock." We did not attempt to climb out, there being no occasion to do so.

Plate 47

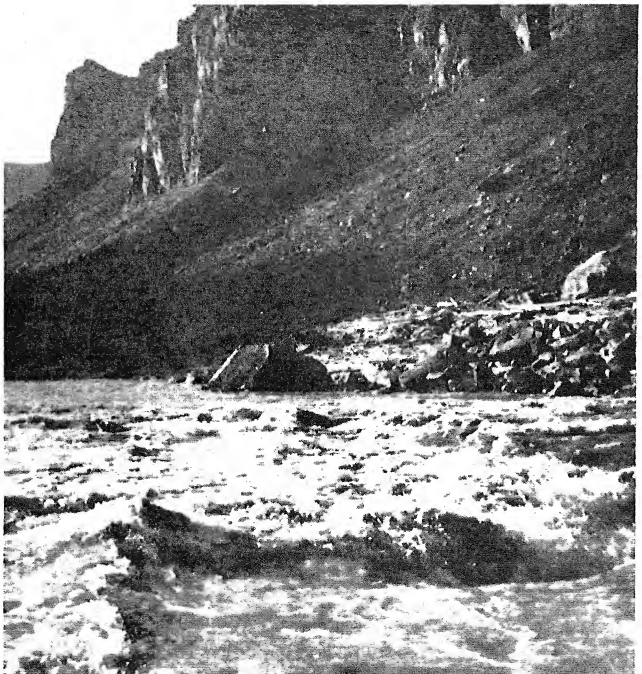

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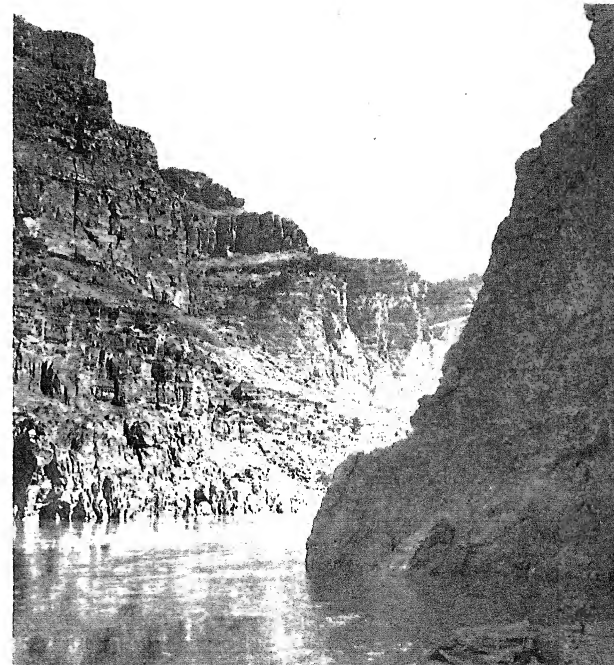
PLATE 48

A



B

PLATE 48A AND B

SCENES IN THE UPPER PART OF CATARACT CANYON

Here grandeur, glory, and desolation are all merged into one.

PLATE 49A

BEDDED ROCKS IN CATARACT CANYON

This part of Cataract Canyon, with walls sixteen hundred to eighteen hundred feet high, sometimes rising sheer from the water, is grand beyond description. The characteristics of such walls as those pictured in Plate 49A are doubtless better understood after some experience in scaling them. This was accomplished by Powell, and also by the Kolb brothers, and since their time few have tried.

Such labor would seem to demand rich reward, and it is evident from published accounts that the scene repays every effort. The view in all directions lies beyond the power of words. Mountains and canyons, cliffs, pinnacles, and buttes, appear as far as the eye can reach, and the range of vision in the clear atmosphere seems to lose itself in the distance that seems neither earth nor sky.

There is discrepancy in the statements as to the height of the walls in this canyon. The topographic maps indicate a height of little more than 1500 feet. Yet the several accounts give heights above the river of 1800 feet, 2800 feet, and 3135 feet. One account states that the canyon is a quarter of a mile wide at a height of 2800 feet. Possibly some of the heights are estimated, while others were obtained with an aneroid barometer.

PLATE 49B

Mouth of Dark Canyon

Near the foot of Cataract Canyon, where Dark Canyon joins that of the Colorado, the walls close in, so that the canyon is narrower than it is in many places farther up stream. The water practically fills the tortuous gorge from wall to wall. In this region of a thousand crags, living things are rare. A few shrubs and stunted plants that may live with little soil are rooted in the sand and among the boulders where water can be reached by the roots. The walls show little evidence of life. Even shrubs which elsewhere seem content with roothold in some crevice of barren rock are absent. Soil is the product of the slow decay of rock. But few fragments of rock remain undisturbed in a place like this long enough to disintegrate into soil. The small fragments washed from the walls are carried away by the river. The large fragments are worn into rounded boulders and polished by the force of the floods. Those shown in the foreground have had only a short journey down the side gorge and have been but partly rounded. During times of flood the river rolls them down stream, grinding the channel deeper until the boulders are in turn ground away and the material dispersed. This is one of the ways in which is formed the 160,000,000 tons of silt which the Colorado carries to the Gulf each year. Thus run the mountains to the sea. The only evidence of animal life we found here was tracks of a band of mountain sheep, but we did not attempt to follow them up Dark Canyon.

Plate 49

A

B

PLATE 50

A

B

PLATE 50A

In Mille Crag Bend

Below the mouth of Dark Canyon the river turns abruptly and flows westward for a few miles, then makes a southward loop between craggy walls which rise rough, barren, and forbidding to heights about thirteen hundred feet above the river. Because of the unusual number of crags and pinnacles in the walls of this loop it was called Mille Crag Bend.

PLATE 50B

In Narrow Canyon

The lowest part of Cataract Canyon, otherwise known as Narrow Canyon, lies below Mille Crag Bend and above the mouth of the Fremont. The walls are high at the eastern end but become lower toward the west until, at the mouth of the Fremont River, they rise only a few feet above the water. This lowering of the walls seems to have impressed the early explorers with a sense of relief. Dellenbaugh states that the world seemed suddenly to open out before them. The significance of this remark may be better appreciated if we recall that he emerged here from a long narrow gorge in which he and his companions had contended for days with the plunging waters of the canyon above.

PLATE 51A

Where the Fremont River Joins the Colorado

The Fremont River is a stream about one hundred and fifty feet wide at its mouth and when first visited, contained undrinkable, muddy, alkaline water which suggested the name Dirty Devil. In Powell's account of the exploration of the Colorado, he names it Dirty Devil, but for some

reason, perhaps because of its inelegance, this expressive name was changed to Fremont before the topographic maps of the region were published. The stream affords drainage to about 4,560 square miles of country, and discharges into the Colorado an average of about 200,000 acre-feet of water each year, or enough to cover 313 square miles one foot deep. The rocks over which the river flows are generally red. The westward inclination of the strata here brings the rocks of Carboniferous age which at Mille Crag Bend are about 1500 feet above the river, down to water level, and the overlying red beds of the Moenkopi formation are seen in the river bluffs which rise about two hundred feet above the water. We found near the mouth of the Fremont a number of springs of hot sulphur water. The waters of these springs differ in quality, suggesting different sources. They are reminders also that the igneous rocks of the Henry Mountains are not far away.

A short distance to the west the rocks which are crossed in Labyrinth and Stillwater canyons appear at the surface. In order from the Colorado westward come first the red, evenly bedded rocks of the Moenkopi formation, sometimes called Painted Desert beds, because of their brilliant colors and the barren character of the country where they outcrop. Beyond these and stratigraphically above them is a thin stratum of hard rock called Shinarump conglomerate and the red sandstone which geologists know as the Chinle formation, and finally the thick, massive sandstone of the Orange Cliffs.

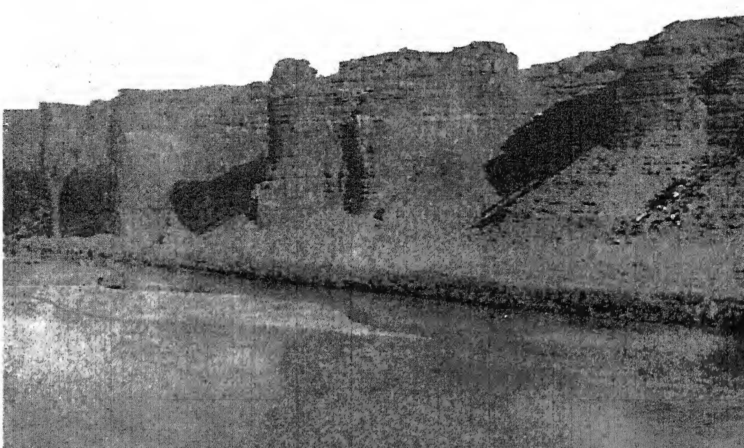
PLATE 51B

MOENKOPI RED BEDS

A few miles south of the mouth of the Fremont River the hard rocks of Carboniferous age which make rough going in Cataract Canyon disappear beneath the river and the bluffs here consist of red beds of Triassic age known to geologists as the Moenkopi formation. They are remark-

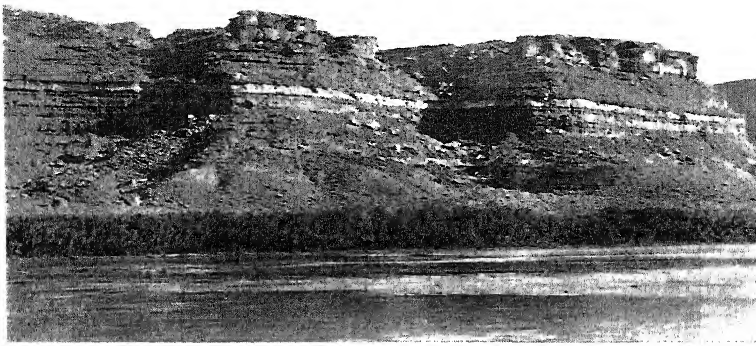
PLATE 51

A



B

PLATE 52



A

B

able in appearance and are persistent over wide areas. Captain Dutton, who saw much of the territory bordering the canyon, writes of these as the most extraordinary group of strata in the west. To the eye they are a never-failing source of wonder. Their characteristics render them in the highest degree conspicuous, curious, and entertaining. The component members preserve their character through wide stretches of country. Wherever their proper horizon is exposed they are always disclosed, and the same well-known features are presented in southwestern Utah, in central Utah, around the junction of the Grand and the Green, and at the base of the Uinta Mountains. So strongly emphasized are the superficial aspects of the beds, and so persistently are they maintained, that only careful measurement and inspection of each constituent layer can impair the *prima facie* conviction that these widely separated exposures are identical.

PLATE 52A

Northern Part of Glen Canyon

Glen Canyon extends from the mouth of the Fremont River to the mouth of the Paria, a distance of about one hundred and seventy miles. Here the river, so turbulent elsewhere, lies in repose, there being only one rapid of any consequence in this entire distance. In the upper part of the canyon, the walls are composed of evenly laminated rocks like those in the photograph on the opposite page. Farther down stream these evenly bedded rocks sink beneath the river level, and the massive sandstone which overlies them in places where it has not been eroded away forms the canyon walls. The reason for the river being tame is found in certain geologic relations. At the foot of this canyon a rock fold, or wrinkle in the face of the earth, crosses the river and again brings the hard rocks of the Carboniferous system to the surface. The Colorado is not able to cut a channel through these hard rocks so readily as through the softer red beds of Glen Canyon, and because the river could not

cut rapidly in the harder rocks, it has been able to smooth out the rough places in the canyon above the fold, and temporarily almost reach a base level of erosion.

PLATE 52B

A Prehistoric Watch Tower

Here as in many other places throughout the region of the lower Colorado stand the ruined homes of the ancient cliff-dwellers. These lovers of inaccessible spots seem to have had possession at one time or another of every crag and canyon wall. Why they were there has been a source of much wonder. Who they were and why they left is still unknown. Surely the enemies who drove them there did not exterminate them, for the defenders of one of these strongholds could defy superior numbers. Did the dwellers of these hidden places die of starvation, or did they seek a happier country when their enemies ceased to trouble them? In the walls of this supposed watch tower are holes at such a height that a man resting on his knees could shoot arrows through them. Lower in the cliffs are many ruins suggesting a community of considerable size.

PLATE 53A

A RAIN-CARVED MONUMENT

For a considerable distance south of the Fremont River the bluffs of the Colorado are composed of Moenkopi red beds. The passage across the river at Dandy Crossing is made possible by the occurrence at the surface here of these relatively soft rocks which have been so broken down on both sides of the stream that approach is possible. Although these red beds are softer than the rocks below them, in many places where they are cut by streams they present nearly vertical faces. They are made up of numerous thin layers of hard sandstone separated by layers of soft shale. When these beds break down, heaps of rock fragments may accumulate which consist of plates of sandstone held together by a paste of red clay. The large plate shown in this photograph has acted like an umbrella, protecting the material under it from the rain. The unprotected parts of the mass have been worn away, leaving a monument to the efficiency of rain as an agent of erosion.

PLATE 53B

MASSIVE RED SANDSTONE IN GLEN CANYON

Farther down in Glen Canyon the walls consist of massive sandstone in two thick layers separated by shaly beds. The sandstone is doubtless the same as that exposed in the walls of Labyrinth Canyon, and exhibits similar characteristics, for the smooth, naked rock stretches out for long distances on either side of the river and here are numerous curiously carved remnants of erosion. There are also many caves and deep holes. Some contain water. In one of these holes or wells twenty feet deep Powell found a tree growing. The excavation was so narrow that he could step from its brink to a limb on the tree and descend to the bottom of the well down a growing ladder. Many of these pockets are potholes worn in the rock by the little rills or inter-

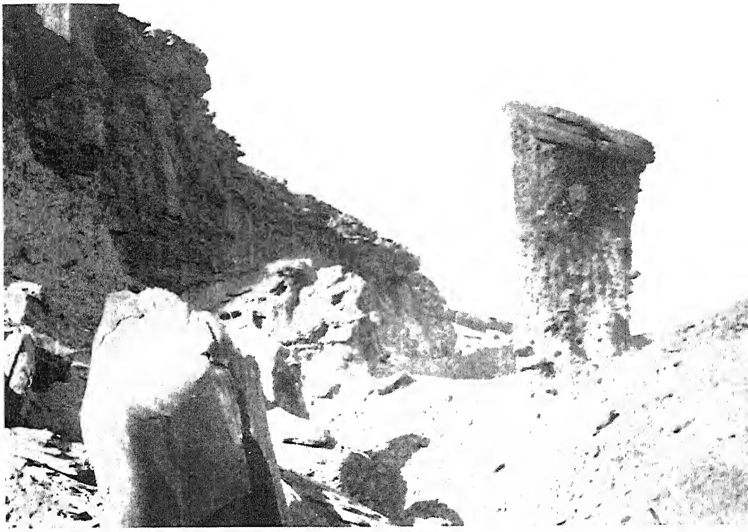
mittent brooks that run during the rains which occasionally fall in this region. In some of the potholes may be found the harder rocks which evidently assisted in their excavation. As the stream flows into the holes and swirls about in them, the fragments of hard rock are carried round and round, grinding the bottom and sides of the holes as they go.

PLATE 54A

The Tapestry Wall of Glen Canyon

This wall of sandstone is called the Tapestry Wall because of the vertical water markings. It was so named by Robert Brewster Stanton, to whom the vertical markings suggested drapery. The walls in this part of the canyon are composed chiefly of homogeneous sandstone and are about one thousand feet high. In some of the bends they are often slightly overhanging, that is, the brink extends out over the water, but in such places the opposite or inside of the curve is generally cut down to irregular, rounded slopes of smooth rock. The vertical portions are commonly not jointed or broken by cracks. Ledges are therefore scarce. The extensive flat faces of the cliffs are beautifully stained by iron oxide so that one may imagine all manner of tapestry effects. From the brink little can be seen except a rocky stretch of country made up of rounded hills, buttes, and mesas of orange colored sandstone in which are worn numerous hollows or potholes, frequently containing water. In some of these depressions are beds of sand and small round balls of stone like marbles, an inch or so in diameter, hard fragments which have been driven round and round by the wind. Thus potholes may be formed by wind as well as by running water.

PLATE 53

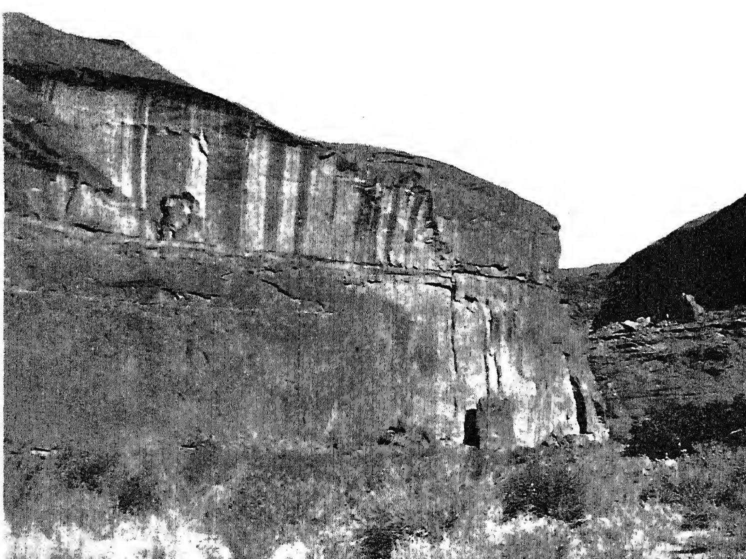


A

B

PLATE 54

A



B

PLATE 54B

Wingate Sandstone in Glen Canyon

The older geologists who worked in the canyon country found the massive sandstone separated into two parts by shaly beds. They called the lower part the Vermilion Cliff sandstone from its occurrence in Vermilion Cliffs, so called because of the brilliantly colored rocks. The upper part was called White Cliff sandstone because of its occurrence in the White Cliffs of Utah. These sandstones were later traced into a region where they are known by the name of Wingate, hence the latter name has been adopted. Those who are familiar with Prof. Herbert E. Gregory's work in the Navajo country, which lies southeast of Glen Canyon, may recognize the lower part of the cliff in the photograph on the opposite page as his Wingate sandstone, the shaly beds as his Todilto formation, and the higher sandstone as the Navajo. Some geologists do not accept as final the correlation implied in the names used. The Navajo sandstone of this locality is not the same as the sandstone called Navajo near San Rafael River (compare table on p. 189), nor is the Todilto of this locality the same as the Todilto of the San Rafael region. The canyon country is large, and many things are still to be learned about it. The lower Wingate or Vermilion Cliff sandstone is the most conspicuous stratum of rock in the canyon country. It is massive and bright red. From it have been carved the most striking of the marvelous plateau landscapes which will be subjects of wonder and delight to all coming generations. The White Cliff sandstone is as conspicuously cross-bedded, containing fossil sand dunes formed at a time in the early part of the Jurassic period, when the canyon country was occupied by a great American Sahara.

PLATE 55A

Glen Canyon

The description of the deep gorge and vertical walls shown in the opposite photograph has led to the popular belief that there are few places where the walls can be scaled, and that once within the confines of the canyon the adventurer must go to the end before he can escape. This belief is kept alive by the nature of the photographs used, and the descriptions published. A good story both in text and in pictorial illustration is desired, and few photographs of broken canyon walls would be acceptable. In spite of Dellenbaugh's correction of this error in a criticism of one of the fabulous accounts of adventure, the statement is frequently made that the walls cannot be scaled. He correctly asserts that there is no difficulty in climbing out of the canyon at many points where the walls are broken down. After having been through the canyon, this writer, who had experienced "the forty-one miles of Cataract Canyon's turmoil, which I venture to say no man could ever forget," says "the whole one hundred and sixty-nine miles of Glen Canyon are simply charming; altogether delightful. One can paddle along in any sort of craft, can leave the river in many places and in general enjoy himself."

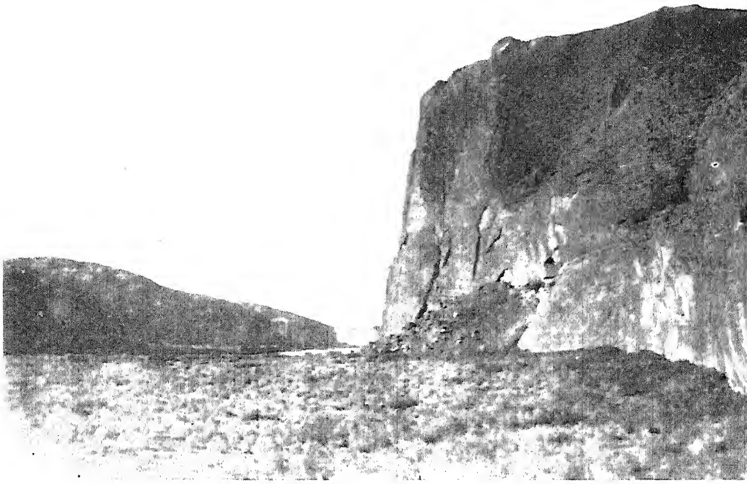
Having been through this part of the river twice, I heartily endorse Dellenbaugh's statement. It is a matter of regret that many writers seem to find it next to impossible to stick to the unvarnished truth in their efforts to produce what they conceive to be a really good story.

PLATE 55B

Picture Writing in Glen Canyon

Picture writing is found on the canyon walls in many places where relatively smooth faces of rock are presented. Apparently the sandstone walls proved particularly tempting to the ancient artists who desired to perpetuate their

PLATE 55



A

B

A

B

ideas. Unfortunately, they left no key by which the treasure of their thoughts may be unlocked. Who were these artists? When did they live? Why were they in the canyons? What events did they record? What actuated them to the labor of chiseling records into the rocks with their clumsy stone tools? These and all the other questions which may arise concerning them as yet remain unanswered. Here the writings stand awaiting the discovery of some key that will render translation possible. Who knows but that here may be records which might throw light on the mysteries of the ancient inhabitants of the Southwest? On the other hand, who knows but that the picture writing tells of nothing more important than the achievement of some hunter. Then, too, they may represent merely an idle pastime, not unlike the pocket-knife art practiced by those who have left their names carved deep in the desks of the country schoolhouse. Some of the figures of these pictographs or petroglyphs, as they are called, are recognized as representing men, others as mountain sheep, birds, serpents, and other living beings. Others represent inanimate things: sun, lightning, and storm. Some groups consist of related figures. One may be a prayer for rain, and another a prayer for a prosperous chase. In other groups the figures are unrelated as if a group of children had each worked into the stone the form which pleased him. Pueblo children of the Southwest do the same at the present time.

PLATE 56A AND B

ORIGIN OF THE NAME OF GLEN CANYON

It is a peculiar characteristic of the sandstone exposed in Glen Canyon that under erosion it assumes a great variety of forms. Conspicuous among these are numerous gulches eroded by small streams tributary to the Colorado, such as that shown in the upper photograph on the opposite page. Some of these are channels of so-called wet-weather streams which flow only during storms. They are short, narrow re-entrants in the walls. Other streams, sup-

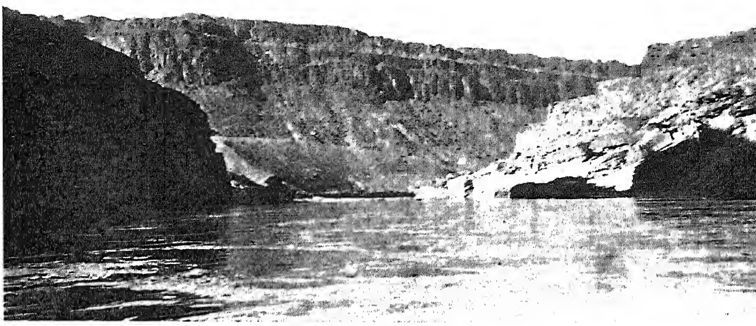
plied partly by springs, flow more regularly and have cut deeper re-entrants. Some of the side canyons are not more than twenty feet wide, twisting back in a tortuous course for perhaps a quarter of a mile, where some expand into huge amphitheaters, domed and cave-like. Alcoves filled with trees and shrubs also open from the river, and there are numerous springs along the cliffs. The sandstone varies in hardness from place to place to such an extent that in the areas between streams it has been strangely carved by rain and wind into a variety of curious forms. So many gulches, alcoves, glens, and hollows of various kinds have been formed in the rock walls that the name Glen Canyon bestowed by Major Powell seems quite appropriate.

PLATE 57A AND B

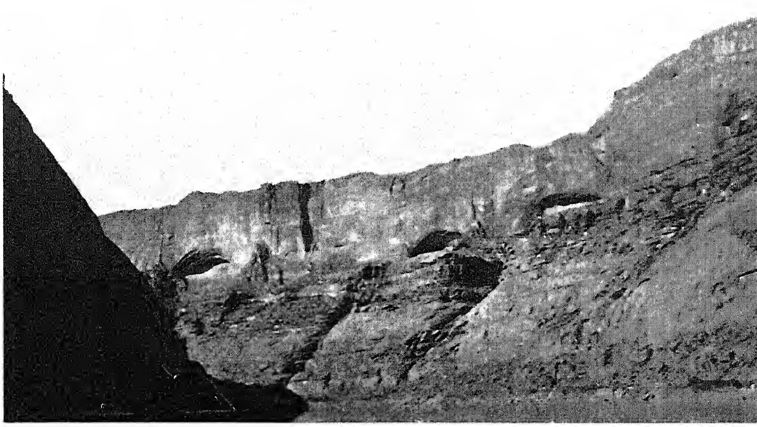
Rock Shelters

The massive sandstone which forms the walls of Glen Canyon appears at a distance to be arranged in well-defined layers like those in the upper photograph on the opposite page. But seen at closer range, as in the lower photograph, each layer has a curious individuality. These layers of sandstone are famous throughout the canyon country for their cave-like hollows known under the general name of rock shelters. Three of these appear in the lower photograph opposite. The higher sandstone is especially rich in these curious shelters. They take on a variety of forms such as natural bridges, windows, panels, and blind arches. According to Professor Gregory, the conditions that permit of the information of these curious hollows in the sandstone are tangential cross-bedding and porosity in rock of uniform composition. The curved cross-bedding is reflected in all the erosion features, the arch being the dominating architectural form. Blind arches and panels are recessed in the cliff faces, and the roofs of niches and rock shelters are vaulted. Erosion of the massive cross-bedded sandstone involves not only disintegration and decomposition, but also

PLATE 57

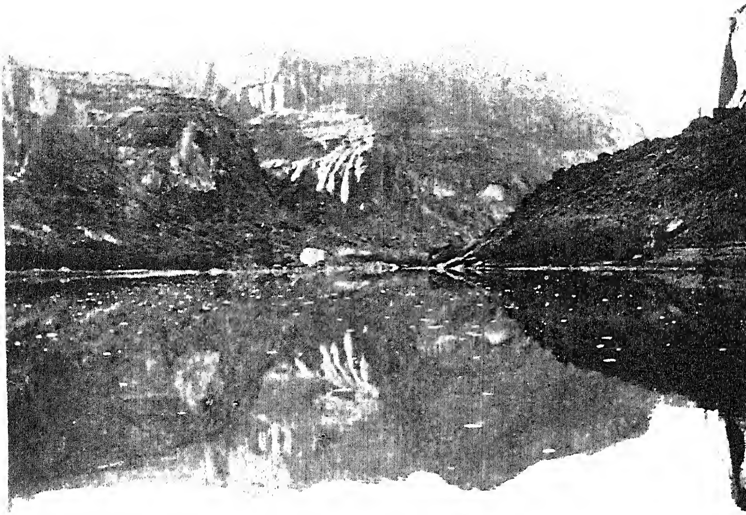


A



B

PLATE 58



A

B

the removal of disks of rock of varying thickness and width. If a wall is thin—a cusp of an entrenched meander or a dike-like buttress—the removal of successive shells from opposite sides may result in a perforation or window. Enlargement of the opening may be such that the remaining arch is a natural bridge. If the wall is too thick to be perforated, niches, blind windows, and panels may result.

PLATE 58A AND B

THE COLORADO IN REPOSE

The Colorado is tumultuous throughout the greater part of its course, but there are places where the quiet waters give no hint of the stormy course they have run, nor of the strenuous times ahead. In Glen Canyon they are serene. The upper photograph on the opposite page was taken about three miles above the mouth of Escalante River early in the morning as the sunlight was breaking over the cliff and lighting up the ribbed promontories of the canyon walls. In the lower photograph, taken a little later, the walls are more brilliantly illuminated, but in the clear atmosphere of this region which makes strong contrasts of light and shade, each shadow appears black.

The white spots on the water in the upper photograph are flecks of foam from a little riffle up stream.

PLATE 59A

CLIFF AND GORGE AT MOUTH OF ESCALANTE RIVER

The massive sandstone of the walls of Glen Canyon occur in two thick layers, separated by beds of thin sandstone and shale. These shaly beds in some places contain layers of limestone and masses of limestone conglomerate which, according to Professor Gregory, seem singularly out of place between the thick beds of sandstone. In some places the layers of shale have sun-cracks, tracks of ancient reptiles, and other markings which give evidence that the

material of which the rocks were made accumulated as mud which was sometimes above water, where it dried in the sun, and where it was trampled by the creatures of Jurassic time. In his description of the Navajo country, Professor Gregory has named these beds the Todilto formation. He calls the sandstone below the shaly beds Wingate, and the sandstone above them Navajo.

PLATE 59B

A Face of Cross-bedded Sandstone in Glen Canyon

The bedding of the sandstone, especially the upper massive layer in the canyon walls, is so peculiar as to excite wonder and admiration. Nor are these peculiarities confined to this canyon. They characterize the sandstone throughout the plateau region. The cross-bedding is on a scale which for extent and perfection of detail is difficult to exaggerate. The prevailing type is tangential. Curved laminae become tangent to adjoining surfaces. Starting as highly inclined arcs of small radii, the cross-bedding laminae gradually decrease in curvature until they merge into contact with the underlying strata. Many groups of curved laminae are sharply truncated along horizontal or inclined surfaces. In places the curved laminae have uninterrupted sweeps of two hundred to three hundred feet. Commonly their length is measured in tens of feet while many cliff faces are decorated by close-set loops and arabesques comparable to the lathe work in steel engraving. To the tangential cross-bedding are due many of the exceptional erosion features—the innumerable pockets, recesses, alcoves, overhanging cliffs, arches, natural bridges, and other forms. The structure and composition of the rock suggests aridity and the uninterrupted control of the winds. The "live dunes" now being formed on the floor of the desert differ only in color from the "frozen dunes" disclosed in the rock walls. It is believed that desert conditions prevailed in this region during the part of Jurassic time when the sands of these rocks were accumulating.

A

B

Plate 60

A

B

PLATE 60A AND B

Thousand-foot Walls Below Mouth of San Juan River

Why are the walls in Glen Canyon so nearly vertical and the cliffs in many places unbroken from top to bottom? When rocks consist of many thin layers of different material, such as hard sandstone and soft shale, the cliff faces are made up of numerous shelves formed on the hard layers. But when the hard layers are hundreds of feet thick, as in Glen Canyon, the rocks break away along the vertical joint planes, leaving smooth-faced cliffs precipitous from bottom to top of the layer. This is illustrated in the lower photograph on the opposite page.

PLATE 61A

Navajo Mountain

One of the attractive features of the canyon country which may be seen from many points is Navajo Mountain. The upper photograph on Plate 61 shows this mountain as it appears from a point below the mouth of the Escalante River. Navajo Mountain is a laccolith, that is, it was formed by molten rock forced up from below and into the sedimentary rocks of the outer crust of the earth, lofting and bending those above the intruding mass. The dome thus formed is of fairly regular outline, although erosion makes the surface rough and irregular. This mountain, situated about ten miles south of San Juan River, differs from other laccolithic mountains in that no igneous rock is exposed at the surface. It appears from a distance as a symmetrical mound rising four thousand feet above Rainbow Plateau, "an island in the midst of a sea of weather-worn and wind-worn, brilliantly-colored sandstone." On nearer approach the mountain, which appears from a distance to be so symmetrical in outline, is found carved by erosion into an intricate succession of sharply

crested ridges and rock-ribbed gorges. So steep and so closely spaced are the canyons leading down to the Colorado and to the San Juan that the interstream ridges stand out like buttresses supporting the mountain on the west and north. The intricacy and grandeur of the stream-carved sculpture are unexcelled in any other part of the Plateau Province.

PLATE 61B

Sand—Old and New

Impressive scenes such as that shown in the lower photograph taken just below Aztec Rapids are termed accidents of erosion. The material of the great cliff is consolidated sand. The material of the unimpressive mass in the foreground at the foot of the cliff is unconsolidated sand. Long ages ago some river brought sand here from mountains that now are gone. These sands were washed by the rains, piled up by the winds of that ancient time, and finally consolidated into sandstone. Here they rested—who shall say how long? Now they are being separated again into loose grains washed down by the rains, sorted by the river, carried down stream by each recurring flood, to find rest—somewhere; to form other sandstones—somewhere; to rest again through unknown periods of time; to be eroded again by some river of the future long after the Colorado and the canyon country have vanished; to be carved into scenery which may be admired by—who shall say what sort of beings?

PLATE 62A

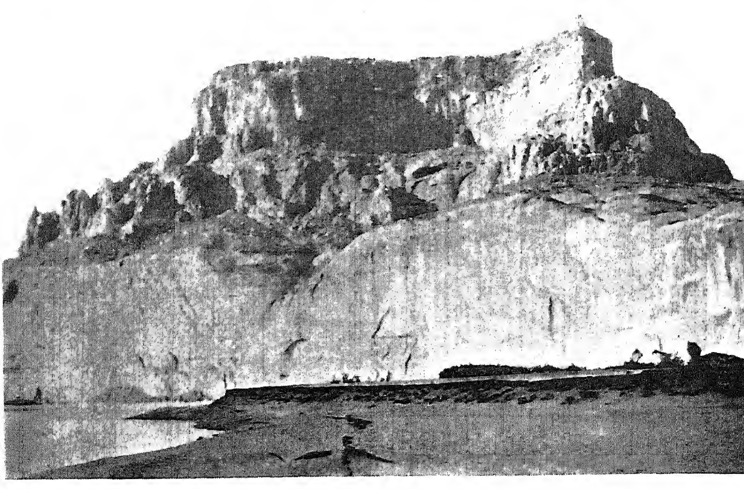
Wall of Sandstone Near Mouth of the San Juan River

Should the traveler climb the wall shown in Plate 61B he would be confronted by such ragged slopes and smooth faces of sandstone as those of Plate 62A.

The walls in Glen Canyon increase steadily in altitude

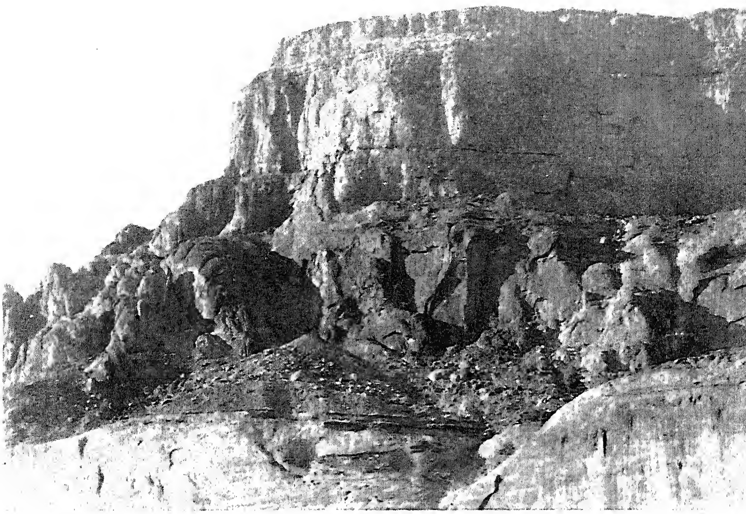
Plate 61

A



B

PLATE 62



A

B

toward the south until near the mouth of the San Juan River they rise more than fifteen hundred feet above the water. Here the river sweeps by many an arc of vertical wall, smooth and unbroken, and by many a curve that is adorned by royal arches, picturesque alcoves, deep beautiful glens, and painted grottoes. One might readily imagine that the walls had been carved in imitation of giant architectural forms. Springs are found in some of the recesses. Around them the walls are green with moss and ferns which have found roothold in the moistened sandstone. The spring water in some instances is the chief cause of the formation of the grotto. The water moistens and softens the sandstone which then crumbles away more readily than it does when dry.

PLATE 62B

Recessed Walls

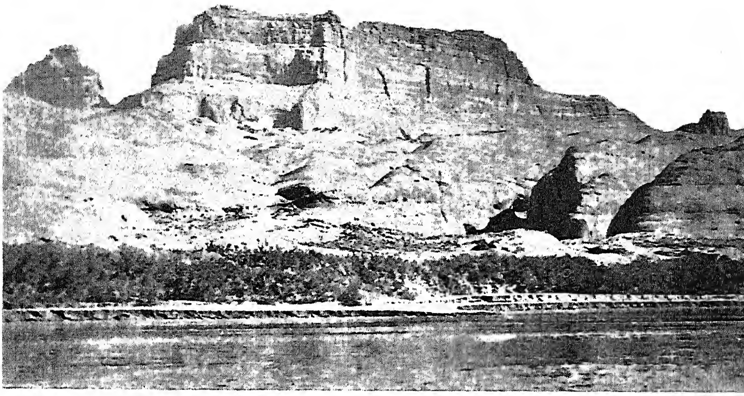
In some respects the canyon walls south of the mouth of the San Juan River are more varied and picturesque than those farther north. One of the recesses characteristic of Glen Canyon, situated two miles south of the mouth of the San Juan, is characteristic of many in this part of the canyon. Major Powell describes it as follows: "On entering, we find a little group of box-elders and cottonwood trees; and turning to the right, we find ourselves in a vast chamber, carved out of the rock. At the upper end there is a clear pool of water, bordered with verdure. Standing by the side of this, we can see the grove at the entrance. The chamber is more than two hundred feet high, five hundred feet long and two hundred feet wide. Through the ceiling, and on through the rocks for a thousand feet above, there is a narrow winding skylight; and this is all carved out by a little stream, which only runs during the few showers that fall now and then in this arid country. The waters from the bare rocks back of the canyon, gathering rapidly into a small channel, have eroded a deep side canyon, through which they run, until they fall into the farther

end of this chamber. The rock at the ceiling is hard, the rock below very soft and friable; and, having cut through the upper hard portion down into the lower and softer, the stream has washed out these friable sandstones; and thus the chamber has been excavated. Here we bring our camp. When 'Old Shady' sings us a song at night, we are pleased to find that this hollow in the rock is filled with sweet sounds. It was doubtless made for an academy of music by its storm-born architect; so we name it Music Temple."

PLATE 63A

Rocks of Varied Composition

In some places the strata are locally unwarped and the massive sandstone which forms the walls in so many places was raised and later removed by erosion. In such places the older rocks appear in the canyon walls. They are not so massive in appearance and are made up of layers of different material. These consist chiefly of red sandstone, soft red shale, and hard gray, pink, and purple limestone. Some of these older rocks are those which in many parts of Arizona and Utah contain petrified trunks of trees like those of the Petrified Forest of Arizona. They are among the most beautifully colored of the rocks in this many-hued region. In some places the cliff faces are striated with bands of purple, pink, and gray, and the landscape is painted with patches and bands of yellow, lavender, pink, maroon, cream, and various shades of red and brown. Patches of blue, of white, and even of black are seen. Erosion has carved the less resistant parts of these rocks into badland forms. Mounds and domes are common, and short, low ridges, isolated or in groups, separated by trench-like valleys of intricate pattern. Where the beds are of hard sandstone the rocks have been carved by erosion into towers, some picturesque, others fantastic. Where layers of hard limestone are present, flat-topped mesas are formed or long lines of cliffs reached by stairways of shale risers and limestone treads.



A

B

PLATE 64

A

B

The most unusual of the architectural features of this sandstone are the caves, alcoves, and other recesses carved out of solid rock. Many hundreds of these cavities have been observed, some small and some large. Many of them were used for shelter, protection, and homes by the ancient cliff dwellers. The most impressive of the sculptured forms of massive sandstone left by erosion are the natural bridges which reach their highest development in the magnificent Rainbow Arch, situated on the side of Navajo Mountain.

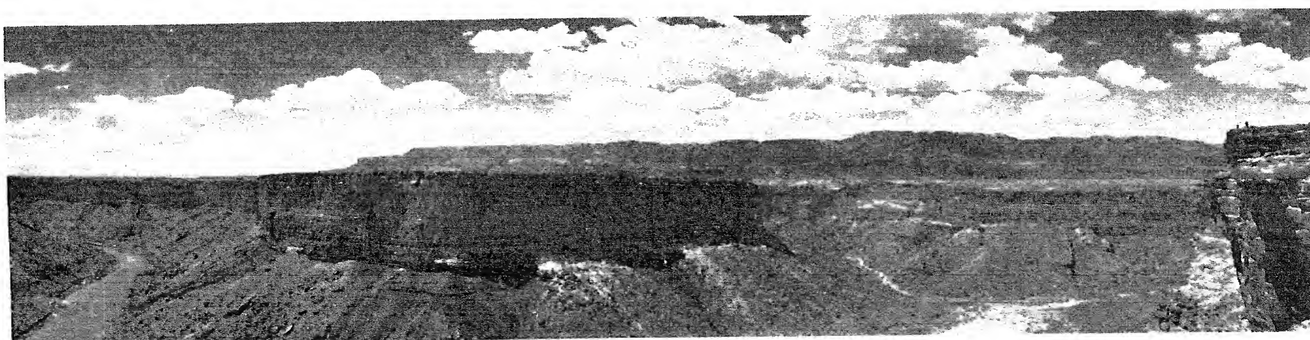
PLATE 65A AND B

SCENES FROM THE RIM

The upper photograph on the opposite page shows a locality in the narrow gorge in the lower part of Glen Canyon which has been selected by engineers as a favorable site for the erection of a dam to control the flood waters of the Colorado for purposes of irrigation and the production of power. The photograph on the opposite page, taken by E. C. La Rue and here used by courtesy of the United States Geological Survey, shows the dam site situated about seven miles up stream from the mouth of Paria River and the surrounding country as seen from the rim of the canyon twelve hundred feet above the water. The lower photograph shows a bend in the river in Marble Canyon at Soap Creek, about eleven miles below Lee's Ferry. In the distance in both photographs appears the great stripped plateau from whose hard rocky floor the softer sedimentary beds were removed long ages ago. The lower photograph illustrates several significant features of the canyon country. The upper part of the canyon consists of solid rock which presents nearly vertical cliffs. Between the cliffs and the river are talus slopes—heaps of loose fragments of rock fallen from the cliffs above. At the extreme left is a small delta where some local flood has washed rock debris from a side gulch into the river. Beyond the canyon is a broad rock shelf from which the younger rocks were stripped during the recession of Echo Cliffs which appear in the distance.

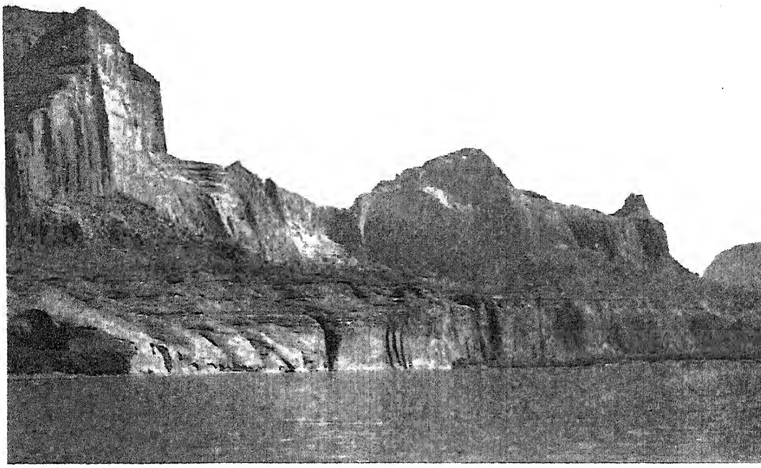
PLATE 105

A



B

PLATE 66



A

B

PLATE 66A

EROSION FEATURES NEAR THE CROSSING OF THE FATHERS

Although the walls are so notably precipitous in Glen Canyon, the river is remarkably mild. From the calm surface of the evenly flowing stream the sides of the gorge rise in towering monuments, recessed walls, and rounded domes to the rolling billowy surface above. Past the mounded billows of orange colored sandstone, oak set glens, and fern decked alcoves, the traveler's boat glides hour after hour, with little to prevent uninterrupted wonder and admiration of the unusual scenes. This is the country of famous natural bridges. About six miles from the river stands Rainbow Bridge, probably the most remarkable arch of rock in the world. Its symmetry and graceful proportions, as well as its size and beauty of color, give to this arch a commanding position among the natural bridges of the world. For the Navajos, according to Professor Gregory, the brige is *Nonnezoshe,* the great stone arch; to the Piutes, its form and bright red tones suggest *Barohoini,* the rainbow, the mythical path of the sun. From the rim of Bridge Canyon it appears as a hoop bent across an inner gorge. The arch rests on a bench of bedded sandstone below which the inner gorge of Bridge Creek is sunk to a depth of eighty feet. Between the chord uniting the springers at the level of this supporting bench and the lower side of the keystone point, the vertical distance is one hundred and eighty-seven feet, and the arch at its summit is forty-two feet thick. The total height of the crown above water is therefore three hundred and nine feet—exceeding that of the second greatest bridge in the United States, Sipapu (the gate of Heaven), in White Canyon, Utah, by eighty-nine feet. The span of the bridge is two hundred and seventy-eight feet.

PLATE 66B

Oak Glens Near Mouth of Navajo Creek

Below the mouth of the San Juan River the features of Glen Canyon are greatly diversified. In some places the walls, especially in the curves of the river, are vertical or even overhanging at those points where the stream has undercut the sides of the canyon. Many curious narrow glens constitute the lateral passageways out of the canyon. Through these one may climb by a narrow stairway perhaps several hundred feet to where a spring bursts out from under an overhanging cliff, and where cottonwoods and willows stand, while along the curves of the brooklet oaks grow and other rich vegetation is seen, in marked contrast to the general appearance of naked rock. Because of these characteristics Major Powell named the recesses Oak Glens. It is difficult to imagine more striking contrasts in scenery than those presented where the towering barren red walls surround and shelter a tiny park filled with a luxuriant growth of plants. It was the carved walls, royal arches, glens, alcoves, gulches, mounds, and monuments that suggested the name of Glen Canyon.

PLATE 67A, B, and C

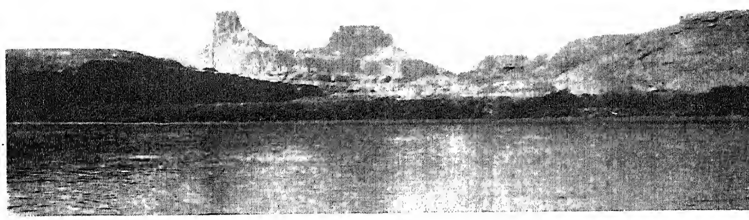
Surprises

The traveler in Glen Canyon will do well to fortify his mind against many a surprise. At one moment from a narrow gorge he may glimpse a towering pinnacle such as that showing at the top on the opposite page and the next moment emerge from the gorge into an opening with sloping walls, from the floor of which buttes and mesas rise with startling abruptness. At the opening shown in (B) the river may be easily reached from either side and crossed without difficulty.

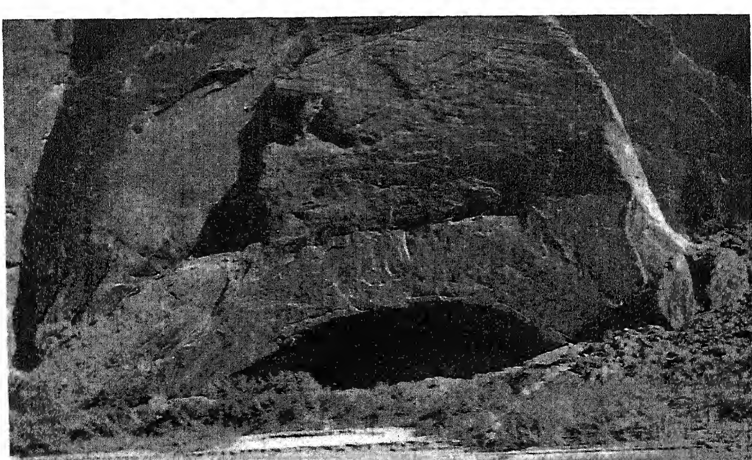
Surprises of another nature are illustrated in the lower

PLATE 67

A



B



C

PLATE 68

A

B

photograph. Here one of the so-called royal arches has formed close to the river level, and is a tempting shelter in time of storm. But experience warns against such shelters, for the storm which drives the boatman to seek refuge may make high water in the river which also may enter the cave. It was in this place near the mouth of Wahweap or Monument Creek that Galloway had a narrow escape some years prior to our last trip. On one of his trapping expeditions in Glen Canyon he was overtaken by a severe storm and, tying his boat to the willows up stream, took refuge in this cave. The storm caused a sudden rise of the river and the water trapped him within his shelter, rising until it touched his chin. Fortunately for him it then subsided and allowed him to escape.

PLATE 68A

Mouth of the Wah-Weap Creek

The upper photograph on the opposite page presents a view of a locality well known because of Powell's illustration entitled Island Monument in his book, "Colorado River of the West" (p. 73). It is called "Sentinel Rock" in Dellenbaugh's "Romance of the Colorado" (p. 291). This photograph was taken where Wah-Weap (Monument) Creek joins the Colorado about seventeen miles above the mouth of the Paria. The wall between the two streams is wedge-shaped, about two hundred feet high and about the same in its up-stream length. It is the end of this wall which is pictured as "Island Monument" in Major Powell's account of the exploration of the Colorado River, and as "Sentinel Rock" by Dellenbaugh in "A Canyon Voyage." The wall is broken down at the rear, not quite three quarters of the distance from its top to the water, making it possible, from one point, to pose the end of the wall in such a way that it appears isolated like a slender monolith. From this point it would be possible with a wide angle lens to duplicate the formerly published photo-

graph. Thus the supposition of some recent observers who failed to recognize "Sentinel Rock" that the monument pictured by the early explorers had been eroded away is not confirmed.

PLATE 68B

A Hanging Valley

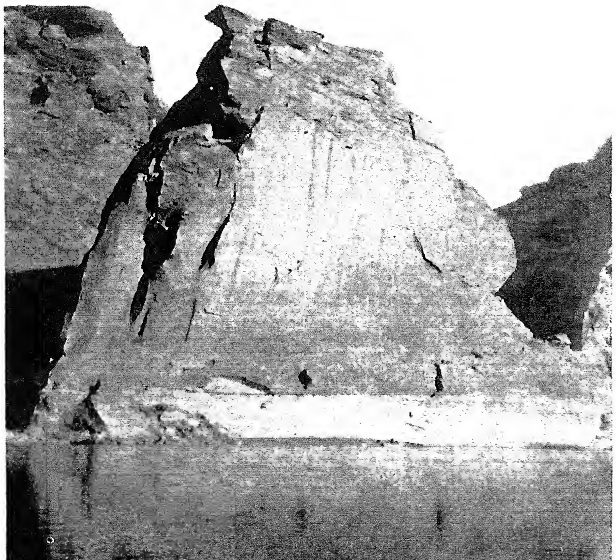
The meaning of a hanging valley such as that shown in the photograph can best be expressed by a statement of the manner in which it was formed. During some previous epoch in the history of the Colorado, before the river had cut the rocky passage now occupied by it to its present depth, the stream flowed over a plain somewhat higher than that now stretching back from the rim on either side of the gorge. On this plain the tributaries of the Colorado entered that river in the ordinary way at the level of the main stream. As the river deepened its channel the tributary also cut into the rocks to form a gorge. But being less powerful than the river, it cut the rocks away more slowly. Furthermore, as the Colorado deepened its canyon, it also widened it to some extent, and in doing so cut away the rocky bed of the tributary stream at its mouth. The net result is a shallow tributary canyon or valley which joins the main canyon at a height far above the river. Because of its position high in the side of the canyon, the tributary is called a "hanging valley" or "hanging canyon."

PLATE 69A AND B

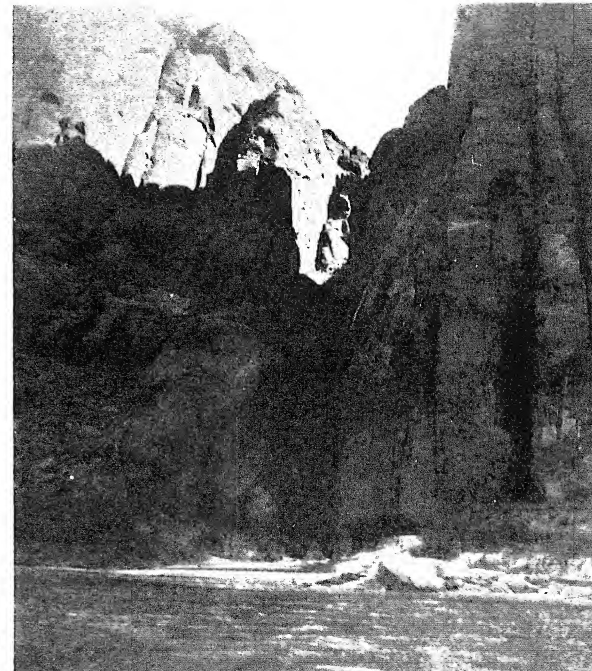
Side View of "Sentinel Rock" and Recess Near Monument Creek

The photograph at the left is a side view of the "monument" shown in Plate 68A. The opening at the left is the mouth of Monument Creek, and that at the right the broken wall between this creek and the river.

Plate 69



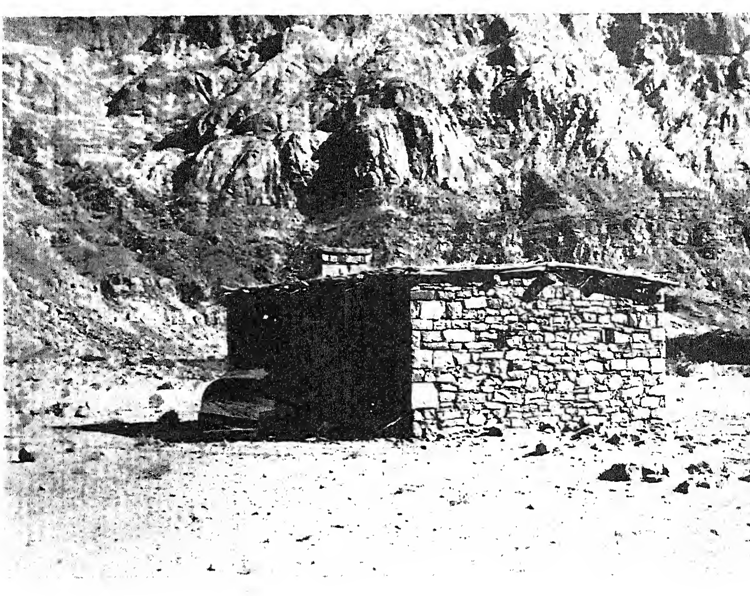
A



B

PLATE 70

A



B

The photograph at the right (B) shows a narrow side gulch a little south of Monument Creek, where a small stream has taken advantage of a line of weakness caused by the vertical jointing of the massive sandstone, and cut a narrow slit back into the dark body of the highlands. Other joints or nearly vertical cracks appear at the right.

PLATE 70A

Near the Mouth of Glen Canyon

The massive sandstone of Glen Canyon is bent up, north of Lee's Ferry where a flexure in the rocks or wrinkle in the face of the earth called Echo Monocline crosses the course of the river. Here this sandstone breaks away to the south and forms Echo Cliffs, one of the most remarkable elements in the landscape of the whole canyon country.

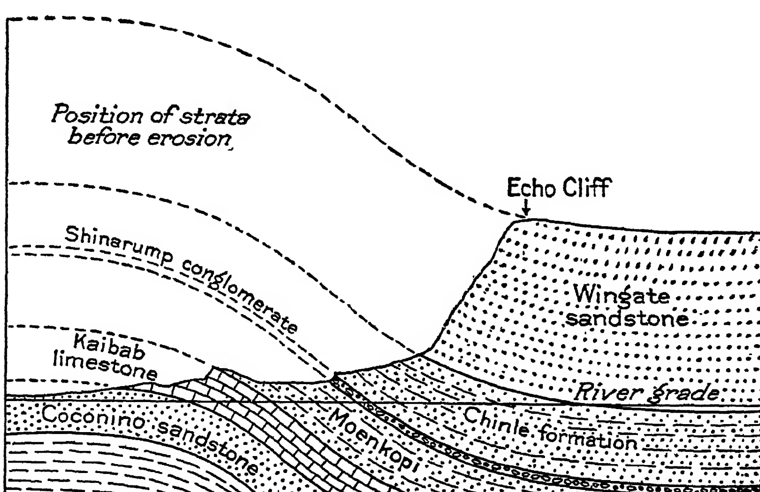


Fig. 5. Diagram showing how the strata are bent in what geologists call a monocline such as that near Lee's Ferry.

PLATE 70B

Old Stone Fort at Lee's Ferry

The fort shown in the photograph on Plate 70B was the stronghold of John D. Lee of Mountain Meadow Massacre fame. Here he lived for some time after the massacre for participation in which he was afterward executed on the scene of his crime. The "fort" is so constructed that natural defenses of cliff and canyon are utilized. Small openings for rifle use may be distinguished in the photograph. The river crossing known as Lee's Ferry is near by. The crossing is made possible by a movement of the earth's crust long ages ago which raised the soft rocks of the Moenkopi and Chinle formations to the level of the river and removed the cliff-making Wingate sandstone. Where the Wingate is present it is usually bordered by cliffs such as those in Glen Canyon. But near Lee's Ferry this formation is replaced at the surface by the softer beds on which gentler slopes have been formed which permit relatively easy approach to the river on both sides. In this way is made possible one of the very few routes across the canyon country. Thus are routes of travel made possible by certain characteristics of rocks, and by the structure of the earth's crust. So does geology influence human activity.

PLATE 71A

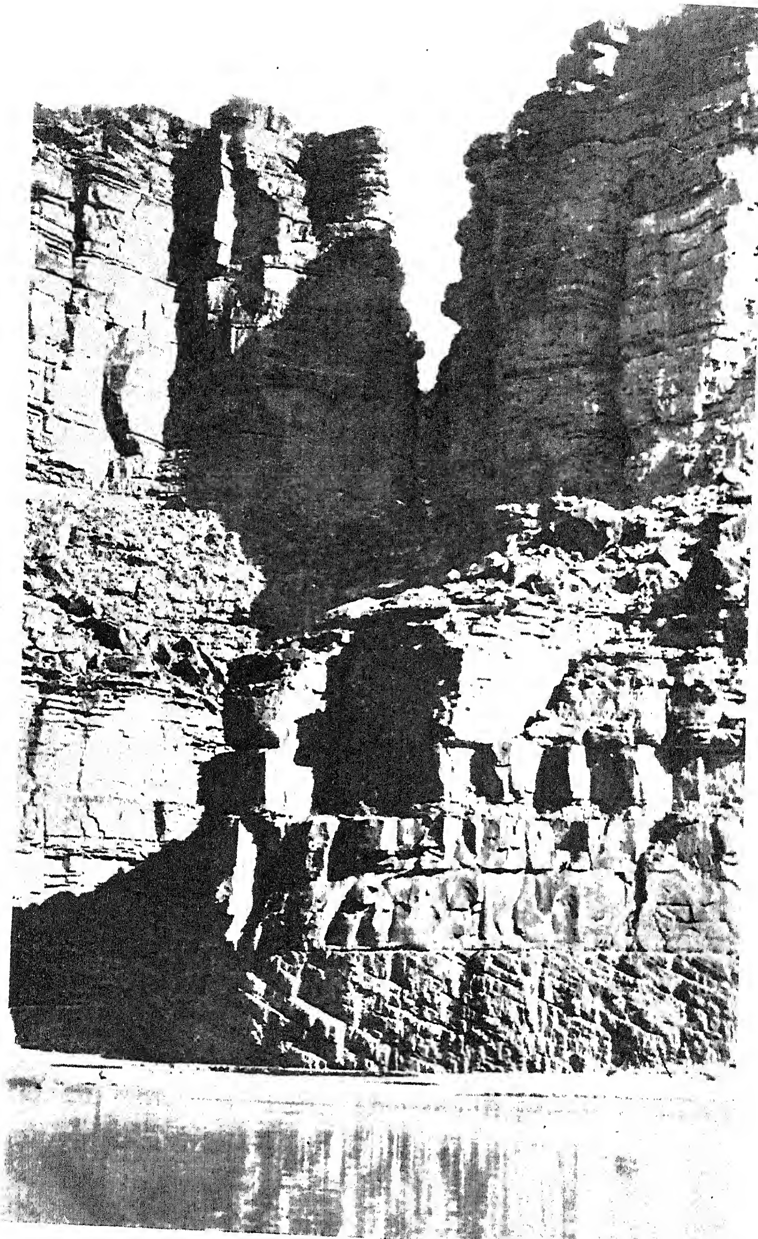
Strata at Echo Monocline

Near the mouth of the Paria the axis of a great wrinkle in the earth's crust called the Echo Monocline crosses the Colorado. In this monocline the hard limestones and sandstones of the Carboniferous age which lie deeply buried under Glen Canyon rise to the surface. North of this monocline the rocks are tilted toward the north so that within a short distance the river, which in Glen Canyon is confined between walls of massive sandstone, here cuts across

PLATE 71

A

B



the eroded edges of the inclined strata which lie below the Wingate, and enters an area of hard cherty limestone called Kaibab. The geologic age and lithologic characteristics of the rocks exposed to view near the mouth of the Paria are indicated in the following table, and their altitude with reference to the river and to the Echo Monocline is shown in the sketch diagram (Fig. 5).

GEOLOGIC TABLE

Age	*Formation name*	*Characteristics*
Jurassic	Wingate sandstone (called Vermilion Cliff by some geologists and La Plata group by others)	Massive, cross-bedded red sandstone; forms cliffs, buttes, and monuments.
Triassic	Chinle formation	Red sandstone and shale variable in character; forms slopes and rolling plains.
	Shinarump conglomerate	Sandstone and pebble rock with petrified wood; forms shelves and caps, mesas, and buttes.
	Moenkopi formation	Red sandstone and shale in many layers; brilliantly colored.
Carboniferous	Kaibab limestone	Hard, cherty limestone; forms conspicuous cliffs.

The rocks represented at the left in the diagram were eroded more than those at the right because they were pushed up higher, bent, and fractured, giving opportunity for erosion to work effectively on them. The massive sandstone was eroded from the higher land exposing the softer rocks under it which, because they were soft, were then eroded away faster than the great sandstone. Hence what was once lowland now lies at the top of the mesa and the site of the former highland is reduced to river level. Thus in time "every valley shall be exalted and every mountain and hill shall be made low; and the uneven shall be made level and the rough places a plain."

PLATE 71B

ACROSS MARBLE CANYON TO VERMILION CLIFF

In the photograph on Plate 71B taken by Professor Gregory, near the head of Marble Canyon, the plain in the foreground is formed on the hard Kaibab limestone where the soft red rocks above it have been eroded away. On the farther side of the canyon the top of which can barely be distinguished in this photograph, is the slope of the many-layered red rocks (Moenkopi) which rise in a series of huge steps to the hard layer of conglomerate (Shinarump) which makes the shelf. The cliff which rises in the background consists of massive red sandstone which is the great cliff-forming stratum throughout the plateau country. No other formation equals it in the extent and variety of cliff exposures. The Vermilion Cliffs extend from the Hurricane fault to the Paria, more than one hundred miles in a straight line, and more than twice that distance if we follow the sinuosities of their escarpment. Throughout this distance they front to the south with a succession of superposed ledges, rarely less than one thousand feet in height and often exceeding one thousand five hundred feet. These escarpments have their distinctive architecture and a structure quite as peculiar to the formation as those of the Shinarump below and the younger Jurassic above. The sandstone consists usually of three or four massive beds of homogeneous sand rock, with a thickness of one hundred to two hundred and fifty feet, separated by shaly layers. The most effective attack of erosion is made primarily against the yielding shales, while the overlying and more obdurate rock is thereby undermined and cleaved off by its vertical joints. Take now a series of these alternating massive layers and softer shales—the long process of erosion gives a series of perpendicular walls and lines of talus slopes. This composite architecture is one of the most persistent features of the formation. Something like it is seen in the Carboniferous strata forming the walls of the

Marble Canyon of the Colorado, but there are also many wide differences both of detail and ensemble.

The hard layer of Shinarump conglomerate forms a shelf because of its resistance to erosion. It consists of sand, pebbles, and fragments of silicified wood firmly cemented together. Sometimes trunks of trees of considerable size, thoroughly silicified, are found, to which the Piute Indians have given the name Shinarump, meaning the weapons of Shinav, their wolf god. This suggested the name of Shinarump conglomerate, by which the layer is known.

PLATE 72

Hard Layers of Rock

A little way below Lee's Ferry the hard, cherty limestone known to geologists as Kaibab, because of its occurrence over wide areas on the Kaibab Plateau, rises above the surface of the water. The river has difficulty in cutting through this hard rock. Here is found the cause of the long stretch of quiet water farther up-stream. In most places Glen Canyon is a straight-walled, flat-bottomed trench with smooth water. The hard rock of the Echo Monocline, particularly this cherty limestone, is an obstacle in the path of the Colorado and is being vigorously eroded. The necessity of cutting the hard rock has delayed corrasion in Glen Canyon and allowed the Colorado to there reduce its course practically to grade. As a stream that has reached a condition which geographers call "grade" does not further deepen its channel, there can be no rapids in stretches of the river where grade has been reached. The fall from the mouth of the San Juan to Lee's Ferry, a distance of seventy-eight miles, averages about one and three quarters feet to a mile. This grade, which might seem excessive in some rivers, is mild for the Colorado. In Marble Canyon, sixty miles long, which lies between the Paria and the mouth of the Little Colorado, the river has a fall of about four hundred feet, an average of nearly

seven feet to the mile. This excessive grade and the resulting rapids are due to the nature of the rocks in which the canyon is cut. After the uneventful journey through Glen Canyon, the change in character of the rocks south of the Paria was viewed with apprehension by the explorers who first entered it. They had learned to observe closely the texture of the rocks in order to judge of the nature of the river below them. In soft strata they found quiet water; in harder rocks they found rapids. Below were the limestones and hard sandstones which had been found in Cataract Canyon. This boded toil and possible danger.

The rocks exposed in Marble Canyon are chiefly of Carboniferous age. The Kaibab limestone shown in the photograph on Plate 72 is first encountered, then the thick massive cross-bedded layer which is probably the same as the one farther south which geologists call Coconino sandstone. Those familiar with the canyon at Bright Angel will recognize the Coconino as the sandstone which makes the persistent light-colored band near the top of the canyon wall.

PLATE 73A

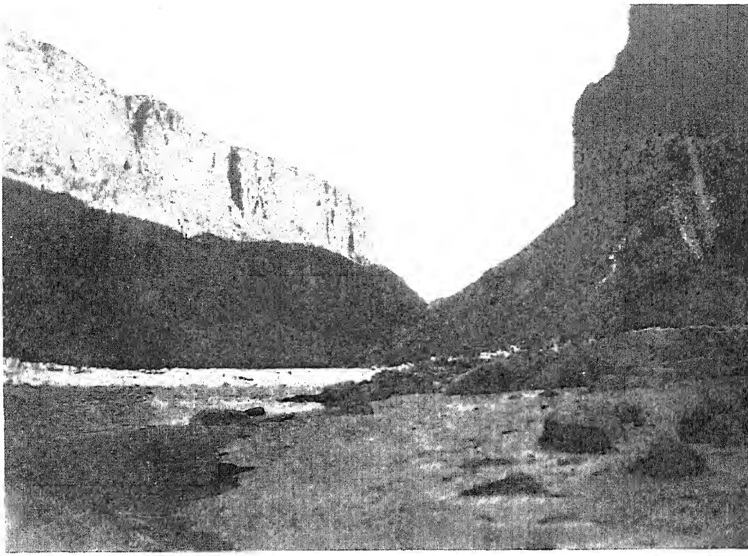
Upper part of Marble Canyon, looking up stream from the first severe rapid situated near the mouth of Badger Creek. Here the river begins a tumultuous part of its course, for a distance of about sixty miles between the Paria and the mouth of the Little Colorado River.

PLATE 73B

View down stream from above the mouth of Soap Creek.

The debris washed into the river by this creek causes the turbulent rapid which at certain stages of water is a particularly difficult one. This photograph shows from below the walls which are seen in Plate 65B from above. Soap Creek comes in from the right and the Colorado here turns to the left.

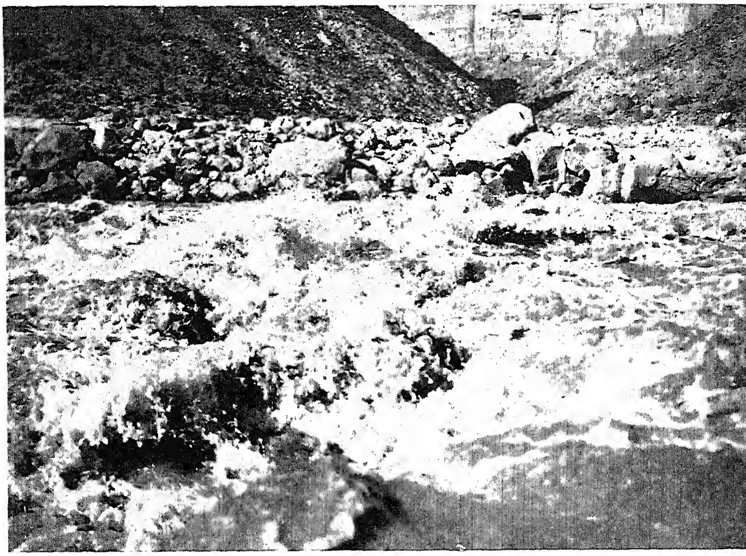
PLATE 73



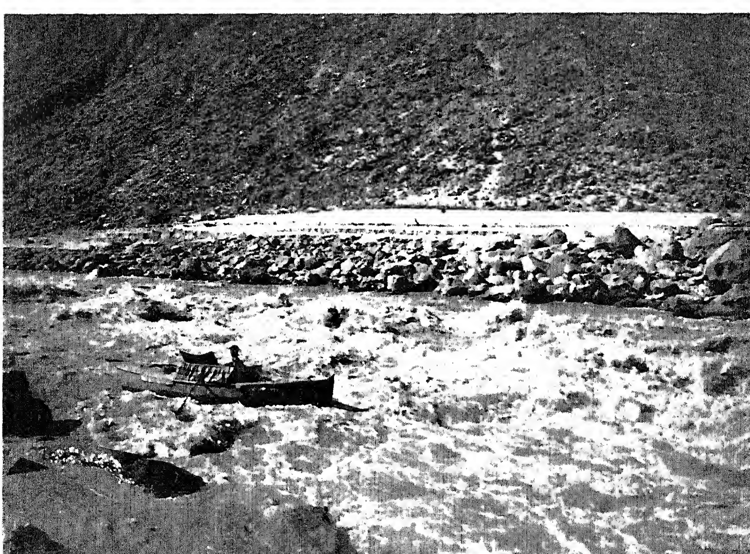
A

B

Plate 74



A



B

PLATE 74A

Force and Tools

Only those who have witnessed a scene like that shown by the photograph opposite can appreciate the force represented. The mammoth stream picks up boulders weighing tons and tosses them about like playthings, smashing them together, dashing them against the canyon walls, and tumbling them along the bottom. Those shown beyond the rapids lie in repose. But the next flood may send them hurtling down the channel to come again to rest miles below. These are some of the tools which that master sculptor, the Colorado, uses to carve out the statuesque forms of the canyons. The force is unmeasured, the tools unnumbered, and the results magnificent shapes standing in splendid array on every hand. And to think that after all they are simply the handiwork of a drop of water and a grain of sand.

PLATE 74B

Boulder Pavement and Flood Plain

"Men may come and men may go, but I go on forever."

Not only does the river have difficulty in cutting its channel through the hard, cherty limestone, but the channel must be cleared of the blocks of rock which fall from the walls. These blocks choke the river here and there, as they are shifted by the floods. A thick bed of large boulders arranged by some flood is shown in the photograph on the opposite page. The level beds of sand covering the boulders were deposited in quieter water, as the river was subsiding, in the last stages of a flood. Thus has been formed a small flood plain. Boulder pavements such as this, but not always covered with sand, are formed by rocks carried down stream by the current during floods. At first the blocks are sharp-edged and angular. But once in the swirling,

booming current, they touch elbows and rub up against trouble until not only do they become polished, but also well fitted to their environment. By constant agitation in the forceful current during high water the boulders grind each other until they become dove-tailed together in an almost solid mass.

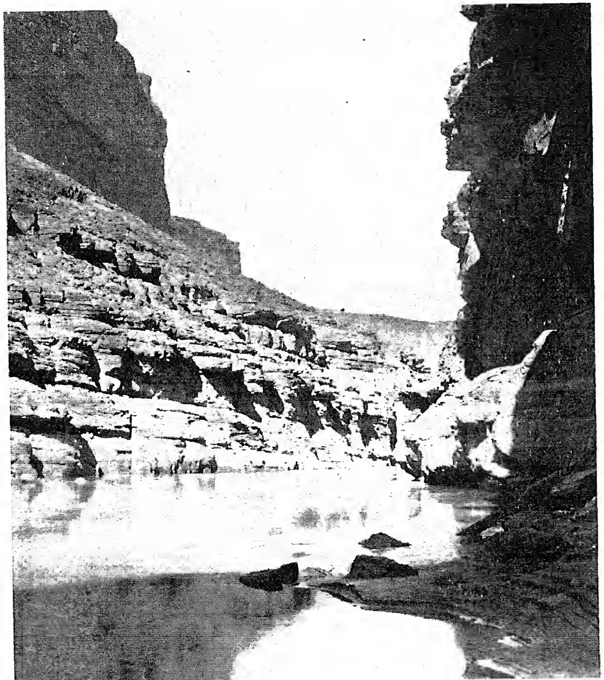
PLATE 75A AND B

CHARACTER OF WALLS IN MARBLE CANYON NEAR RAPID NO. 13

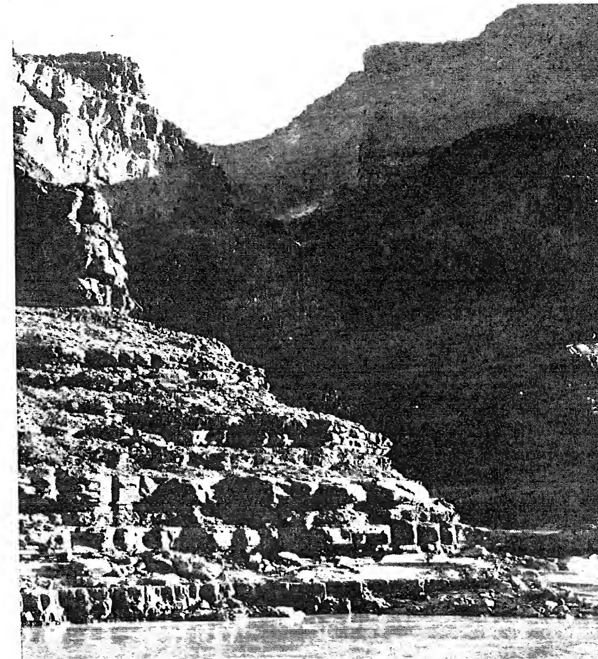
Three of the four geologic formations exposed in the walls of the upper part of Marble Canyon are makers of conspicuous cliffs. The upper two, the Kaibab limestone and the underlying sandstone, occurring together form high walls which are extremely precipitous. The rocks below the sandstone, formerly known to students of the Grand Canyon as the Supai formation, and later as the Hermit shale, are softer than the others and break down in such a way that a slope or series of steps forms at the surface. Below the Supai is the greatest cliff-making formation of the whole canyon country. It is called Redwall limestone because of the conspicuous red cliffs which it forms in Grand Canyon. It is the great cliff-maker in Marble Canyon also and the chief source of the marble which gives this canyon its name. Here in many places the canyon walls are perpendicular. They give to the landscape striking contrasts and a generally hard aspect. The canyon in many places is narrow, and the vertical walls become higher and more forbidding down stream. Whether the landscape is artistic or inartistic depends on the point of view; whether attractive or repellent, on the mood of the observer. It is never restful, never soothing.

In the photograph to the left on the opposite page is an illustration of the meaning of a topographic map. Sand was deposited here at the side of the river in a nook sheltered by some rocks during a period of moderately high water. As the water subsided the wavelets cut horizontal

PLATE 75



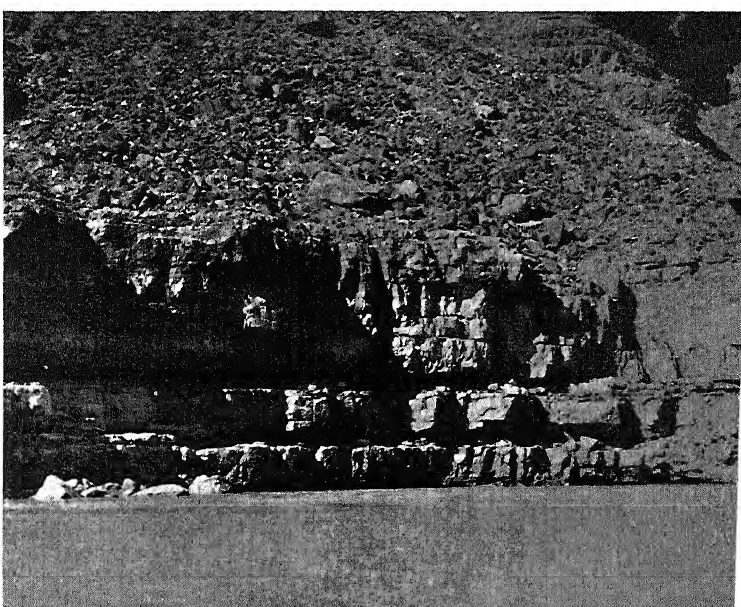
A



B

PLATE 76

A



B

notches in the side of the bed of sand. Each notch represents the water level at the time the notch was cut, and each makes a sinuous line which indicates equivalent altitudes —neglecting the slight inclination of the surface of the water due to the grade of the river—just as a sinuous line on a topographic map indicates points of equal altitude. This is, however, much more clearly shown in Plate 112B, to which the reader's attention is directed.

PLATE 76A AND B

Farther down in Marble Canyon

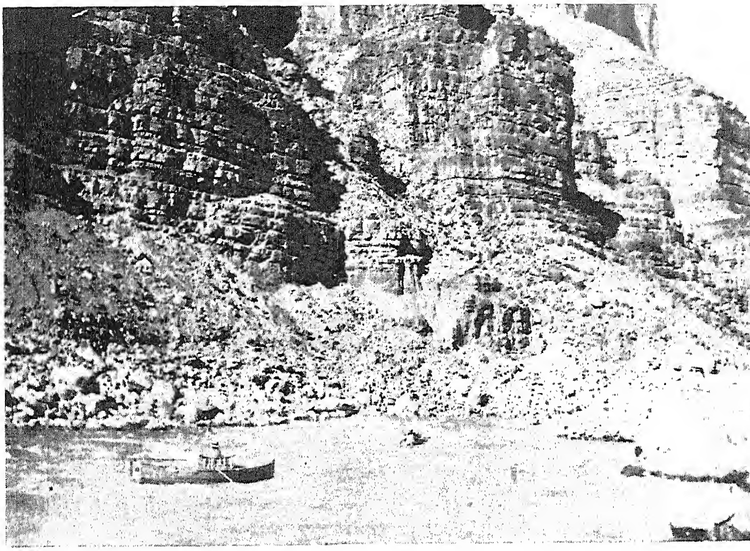
PLATE 77A AND B

ROUGH GOING IN MARBLE CANYON

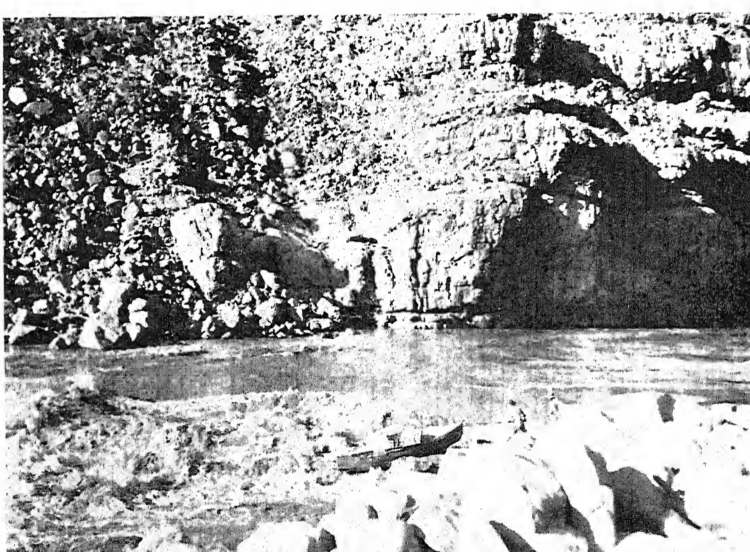
The upper photograph shows the small rapid No. 24 below Lee's Ferry. It must be borne in mind that the rapids we found and to which we gave numbers for our records might not be the same as someone else would encounter on a similar trip, but at a different stage of water. A higher stage would obliterate some lesser ones while a lower stage would accentuate them, and at greatest flood time practically all would disappear because the river would then become one tremendous rapid throughout the Marble and the Grand canyons.

The lower photograph on the opposite page shows "lining" a boat to avoid submerged rocks at the head of Rapid No. 25. The boat was reoccupied in the eddy shown in the lower corner of the picture at the left.

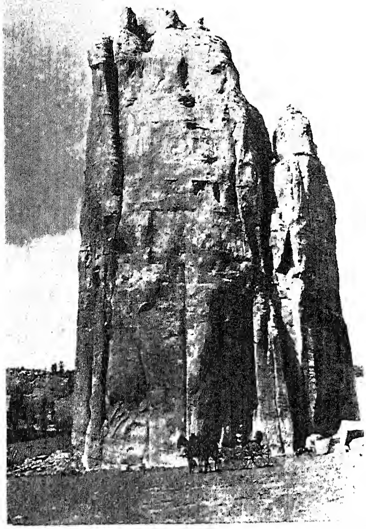
Plate 77



A

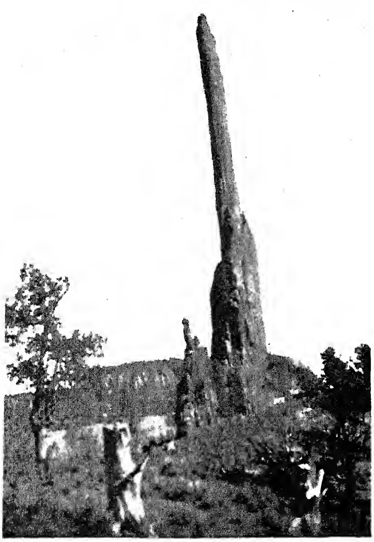


B



A

B



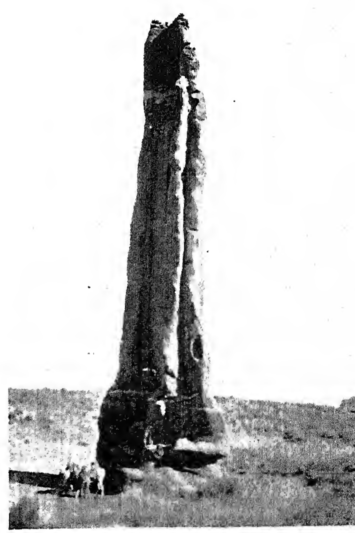


PLATE 78A, B, C, AND D

NATURAL MONUMENTS OF THE WINGATE SANDSTONE

Wherever the Wingate sandstone (La Plata or Vermilion Cliff) is exposed remnants of erosion, usually called natural monuments, are numerous. Four of these from Professor Gregory's collection of photographs for the United States Geological Survey are shown on the opposite page. "The Haystack" (upper left) near St. Michaels, Arizona, is a characteristic form with vertical walls rising abruptly from the sandy plain. The manner in which these remnants are left by erosion is illustrated in the cliffs and towers (upper right). The cliff at the right has been cut by rain and wind at a joint crack until a tower is partly separated from the parent mass. At the left is a tower separated long ago by the same process now at work on the partly formed tower in the center. A monument near Crystal, Arizona (lower left), and another known as Edna Needle on Carson Mesa, Arizona (lower right), represent advanced stages of erosion.

PLATE 79A, B, AND C

PAINTED DESERT BEDS

The rocks of the Painted Desert known to geologists as the Moenkopi formation are brilliantly colored and consist of many layers of red sandstone separated by shale of many different colors. The layers differ so much in color that in cliff faces the beds have a banded appearance, as shown in the photograph at upper left. On closer inspection they are seen to be intricately etched by the weather, the hard layers resisting the force of rain and wind to a greater degree than the soft layers. This process results in such ornately etched forms as those locally called Punch and Judy (below) and many curiously carved forms like those shown in the upper right hand corner.

The two photographs above are from Professor Gregory's collection and the one below from the Jackson collection, both with the United States Geological Survey.

PLATE 79

A

B

C

PLATE 80

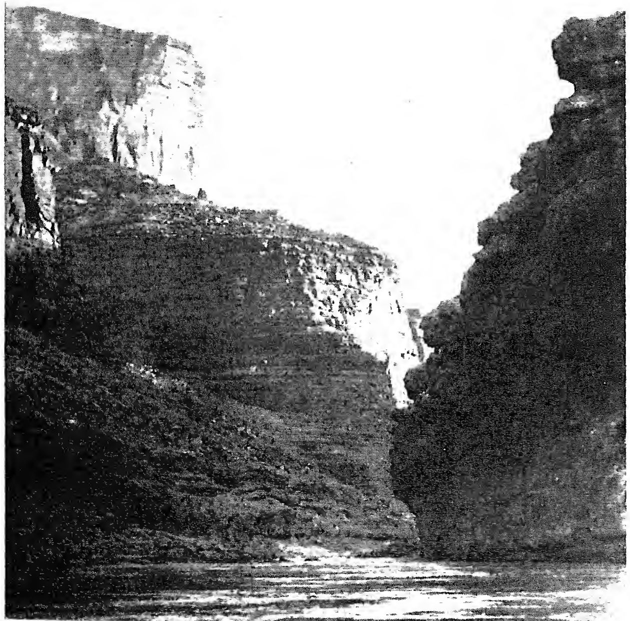


PLATE 80A AND B

A GEOLOGIST'S PARADISE

Where rocks are perfectly exposed as they are in Marble Canyon the geologist can see every layer and examine every detail. In this canyon the rocks have a northward inclination, rising toward the south, the direction of the flow of the river. In some places the walls of marble are nearly vertical for about seven hundred feet, and above it the red walls rise, by four huge terraces, to two thousand feet or more. One of these terraces appears in the photograph at the left. The average width of the canyon at the top is about one and one quarter miles. Its breadth at the water line is sometimes not more than one hundred and twenty-five feet. The rock formations in Marble Canyon probably differ in thickness from the same formations in Grand Canyon farther down stream, but otherwise they are essentially the same. There the canyon rim consists of dense, cherty Kaibab limestone four hundred to six hundred feet thick. Above it at some distance from the river are the Moenkopi red beds. Below the Kaibab is the creamy-white, intensely cross-bedded Coconino sandstone which forms a single massive bed two hundred and fifty to three hundred and fifty feet thick. Its light color contrasts sharply with the red of the underlying Supai formation. The Supai, twelve hundred and fifty to fourteen hundred feet thick where it has been measured in Grand Canyon, consists of red sandstone in relatively hard layers and soft red shale. These three formations constitute the Aubrey Group of many writers. Below the Supai red beds is the great layer of light colored crystalline limestone, six hundred to seven hundred feet thick, which is called Redwall because the conspicuous cliffs which it forms in the canyon walls are stained red, from the Aubrey group above. This is the chief source of the marble in Marble Canyon. Below the Redwall limestone in some places, especially near the lower end of the canyon, is the shale, limestone, and sandstone of the Tonto group.

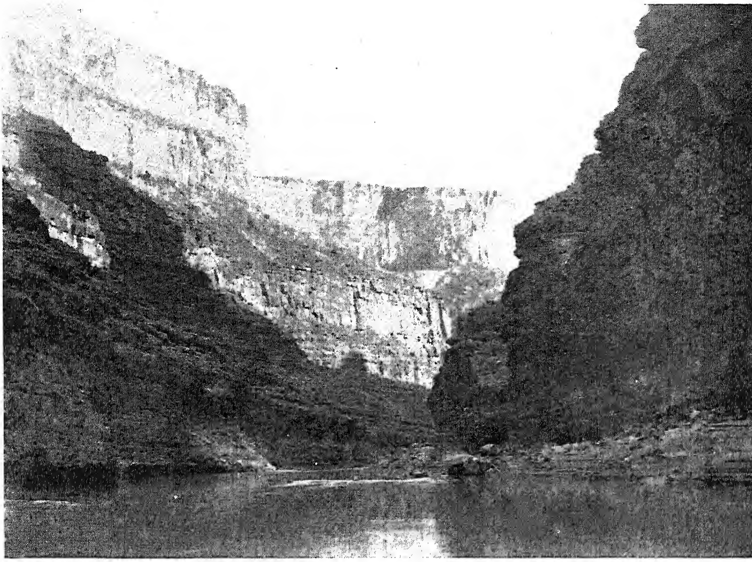
The rocks are made more accessible by the occurrence of side gulches such as that shown in the photograph to the right where a narrow slit has been eroded in the marble. Through these the observer may gain access to places high in the walls otherwise unattainable.

PLATE 81

Central Part of Marble Canyon

The upper photograph is a view up stream from the head of Rapid No. 29 and the lower one down stream from Rapid No. 30.

PLATE 81

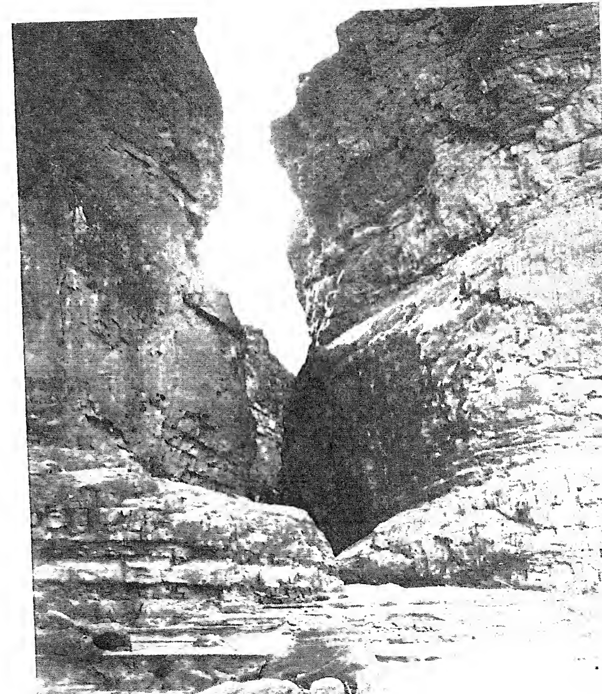


A

B

PLATE 82

A



B

PLATE 82A AND B

TRIBUTARY CANYONS

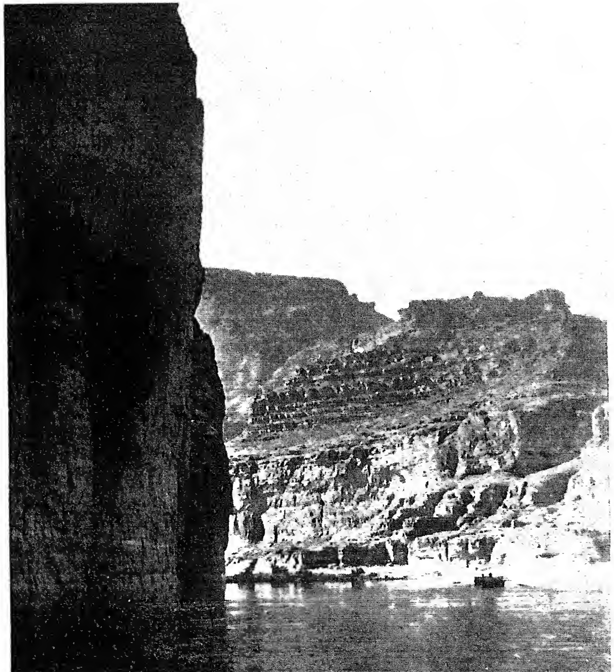
The photograph opposite at the left (A) shows a narrow, gloomy part of Marble Canyon where the walls rise abruptly from the water. The photograph to the right (B) shows the mouth of one of the slit-like gorges tributary to this canyon. Narrow gashes back into the heart of the rocks that form the plateau through which the canyon is cut are not uncommon. They are especially conspicuous in Marble Canyon because of the nature of the rocks. All except the rocks of the Supai formation normally form straight-walled cliffs. Through such gorges as this much of the drainage of the plateau finds its way to the main stream. At ordinary times there may be a slight trickle of water in the gorge or the bed may be dry. But during storms a raging torrent descends two thousand feet or more from the plateau above, a rolling, plunging mass of thin mud bearing sand and boulders which grind with terrific energy on the rock floor of the gorge. In such places the corrasion of the bed so far exceeds other forces of erosion that narrow trenches result, such as the one shown, some with vertical walls, and some in which the water has undercut the rocks to such an extent that great masses of them overhang the stream.

PLATE 83A AND B

DETAILS OF MARBLE CANYON

The photograph to the left (A) is looking down stream from a point a little way below Rapid No. 34. The one to the right (B) is from half a mile below this rapid, and a short distance above the spot Major Powell named Vasey's Paradise. The dark spots in the walls in the middle foreground are the openings of channels that carry streams at times of storm.

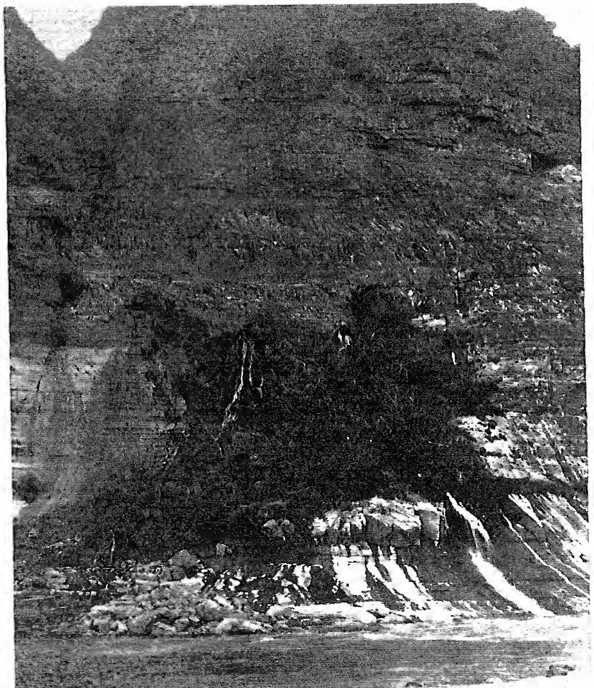
PLATE 83



A

B

Plate 84



B

PLATE 84A

Vasey's Paradise

In the rocks of Marble Canyon, as in the limestone of other regions, caves have formed where parts of the limestone have been dissolved along the underground water courses. Sinking its great trench through the limestone, the river cut through some of these caves so that they open in the canyon wall. Some are dry, the underground streams which formed them having found other exits. Others still contain flowing water. Several "live" caves open into Marble Canyon at a place called Vasey's Paradise, a name given in honor of Dr. George W. Vasey, who was at one time a botanist in the United States Department of Agriculture. The water issuing from these caves keeps the canyon wall perpetually wet, supplying the moisture necessary for plant life. Here in this desert of red rock is the beautiful green paradise shown in the photograph at the left on the opposite page. Around the window-like openings in the wall bunches of moss and ferns are draped, while from the side, about one hundred feet up from the river, clear water breaks forth and falls as silvery spray on the verdure below. It is a striking and unusual picture, the only green visible in the landscape, for the surrounding walls from brink to river are absolutely barren of any vegetation.

PLATE 84B

South of Vasey's Paradise

Every detail of the rocks stands out conspicuously in such walls as those of Marble Canyon. No vegetable growth obscures them. Over great stretches of wall no tree is seen nor any shrub. The steep cliffs are cleared by wind and rain so that no soil accumulates, and in few places do many fragments of rock lodge, even temporarily. The cliff faces

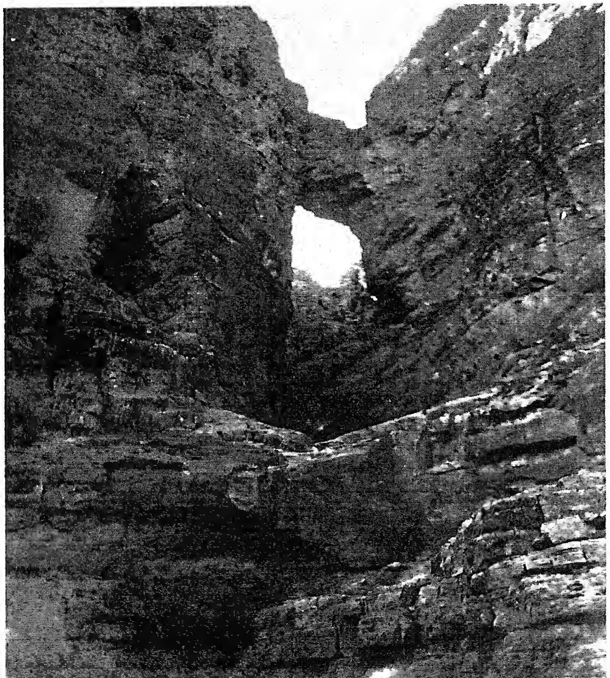
are often polished, revealing beautiful marble of many colors, white, gray, pink, and purple, with saffron tints, in never ending variety.

PLATE 85A AND B

(A) A natural bridge over a side gulch. A second bridge over the same gulch, in the middle foreground, is too low for the sky to show under it.

(B) View in lower Marble Canyon looking up stream from Rapid No. 38.

Plate 85



A

B

PLATE 86

A

B

PLATE 86A AND B

LOWER MARBLE CANYON

(A) Looking down stream from Rapid 38, and (B) A side canyon.

PLATE 87A

Marble Walls

The walls in the southern part of Marble Canyon rise vertically about eight hundred feet above the river, and then by a succession of huge shelves to probably three thousand feet or more. The outlook down stream between such walls is almost overpowering in its impressiveness. This feeling is increased by the openings of caves in the great limestone. For some reason caverns appeal strongly to the imagination and have given rise to many a weird flight of fancy. No wonder the superstitious aborigines peopled the canyons with unearthly beings of their imagination.

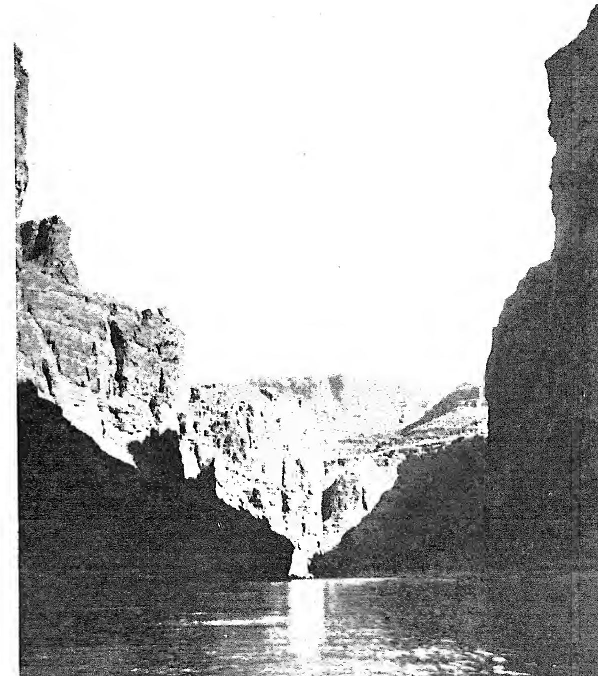
PLATE 87B

Sunshine and Shadow

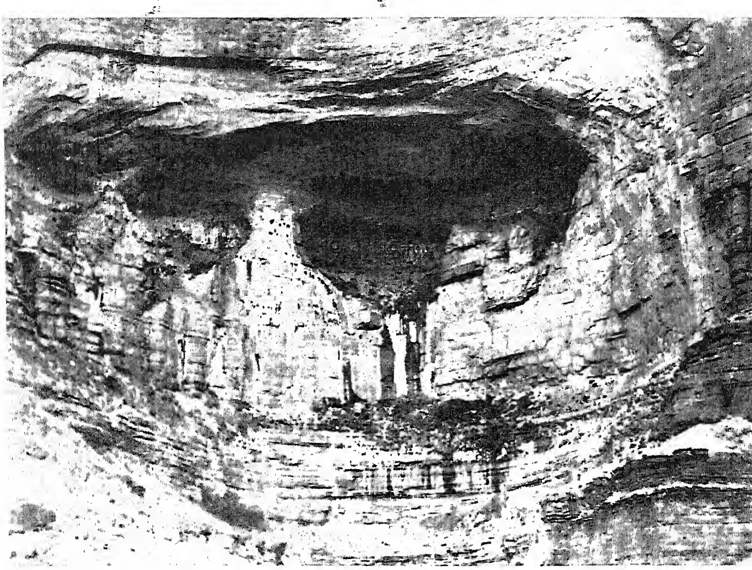
Marble Canyon is a place of high lights and deep shadows. The strong illumination of the walls where the rays of the sun strike them contrasts sharply with the shadowy depths of the great gorge. The sharp contrast here between light and shade is due to the clear atmosphere. It is difficult in the canyons of the Colorado River to find a landscape lighted uniformly enough to secure a photograph of even tone. From one side or another the light is cut off by the rim of the canyon or by some promontory. The weirdness of the shadowy depths is increased by the numerous remnants of erosion.

PLATE 87

A



B



A

B

PLATE 88A

An Amphitheater

The canyon walls become higher and higher toward the south in Marble Canyon and the colossal precipices looming on all sides seem to overwhelm the river by their magnificence. In its rapid sweeping course about the buttresses the current has undercut the walls in many places, forming great hollows in the sides of the canyon. Some of these are of recent origin and are at the river level. Others are above the reach of even the highest waters and were worn in the rock before the river had cut the gorge to its present depth. The upper photograph on the opposite page shows such a hollow in the wall. Powell remarks that this semicircular chamber if used for a theater "would give sitting to 50,000 people."

PLATE 88B

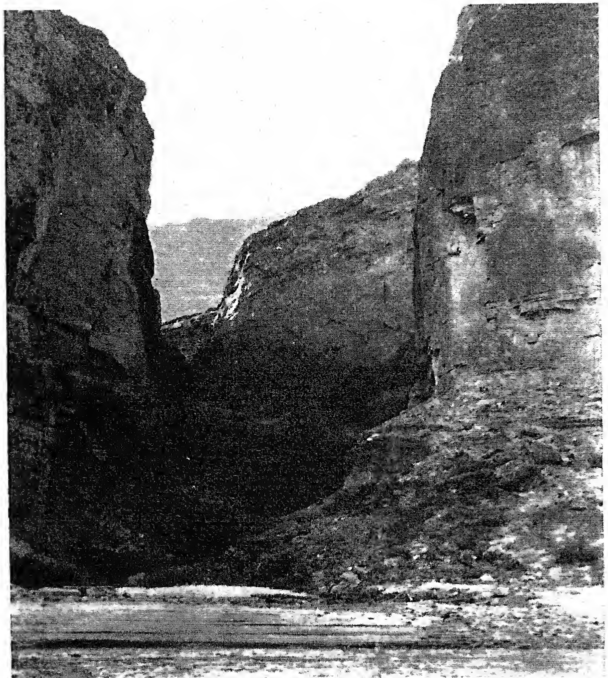
A Marble Prison

A view in Marble Canyon down stream from Rapid 42.

PLATE 89A AND B

(A) A side canyon.
(B) Distant view (up stream) of amphitheater.

PLATE 89

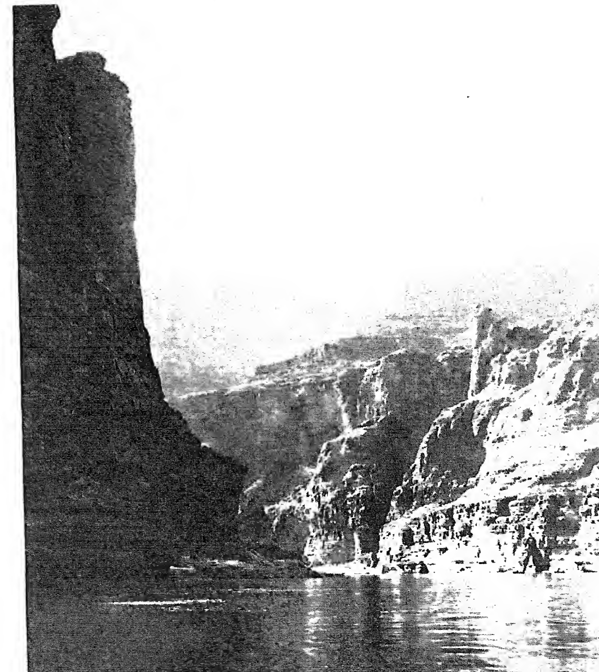


A

B

Plate 90

A



B

PLATE 90A AND B

COLOSSAL WALLS NEAR SOUTHERN END OF MARBLE CANYON

Vertical walls such as those shown in the photographs on the opposite page are not rare in Marble Canyon. The thick layers of hard rock are jointed or cracked into long, upright columns which break away, leaving the cliffs nearly perpendicular. In these narrow confines the flood waters rise to unusual heights. Here we found driftwood one hundred and seven feet above the river, where it had lodged at flood time. It is well to remember that drift is only deposited by a falling, never by a rising stream. Therefore, the flood leaving this particular driftwood must have reached even a slightly higher level. Here, however, the Canyon makes a rather abrupt turn and is narrow. Therefore, because of their velocity at flood time, the waters would pile up on the outside of the curve where we found the drift for our camp fire.

PLATE 91A

Silent Depths

It is a peculiar feature of these walls that many projections extend out into the river as if the wall were buttressed for support. The walls themselves are half a mile high, and these buttresses are on a corresponding scale, jutting into the river scores of feet. In the recesses between these projections there are quiet bays, excepting perhaps at the foot of a rapid, where there are dancing eddies and whirlpools. The walls, buttresses, and chambers are all of marble. A more impressive corridor can scarcely be imagined.

PLATE 91B

Marble Canyon Near the Entrance to the Grand Canyon National Park

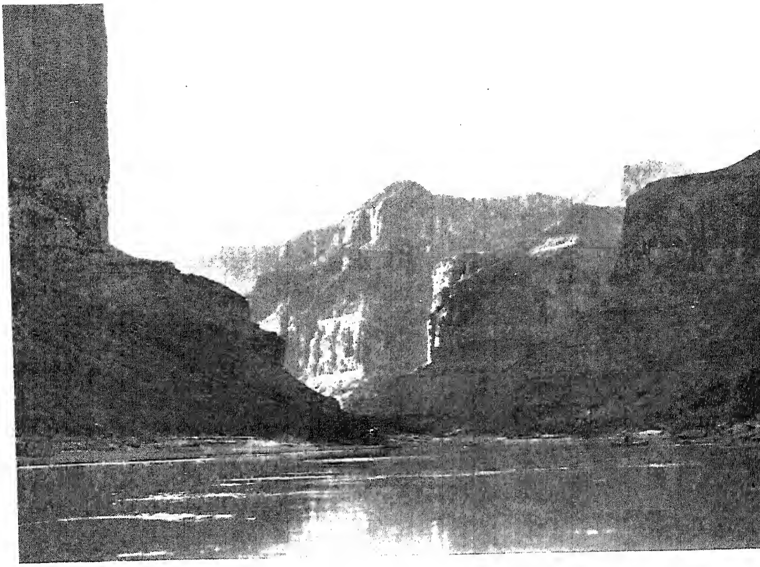
At the mouth of Nankoweap Valley, about nine miles north of the Little Colorado, the river enters the Grand Canyon National Park, through whose nine hundred and fifty-eight square miles of natural wonders it winds for more than one hundred miles. Here is a wonderland unexcelled anywhere on the globe. The Grand Canyon is one of earth's greatest spectacles. It is useless to compare it with great features of dissimilar nature. Of its own kind there is nothing in the world which surpasses it or even approaches it in form, in magnitude, or in the brilliancy of its glowing colors.

PLATE 91

A

B

Plate 92



A

B

PLATE 92A

TONTO SHALE AND REDWALL LIMESTONE

The rocks under the marble of the Redwall limestone are of a peculiar and distinct type. They are called Muav limestone from the excellent exposures of them in Muav Canyon. They consist of impure, thin-bedded, bluish limestone in numerous layers separated by buff or greenish, shaly material. This interbedding of hard and soft layers causes the rocks to weather in such a way that their outcropping edges in the walls of the canyon have a banded appearance. The Redwall limestone forms the great vertical ledge higher in the canyon walls, and still higher are the cliffs at the rim formed by the Kaibab limestone and the Coconino sandstone. Because of its hardness the Kaibab is the controlling stratum of the highlands on either side of the river. It is the cap rock of the plateau to the east whose rim north of the Little Colorado is known as the Desert Façade. This plateau is covered some distance back from the rim with bright red rocks. Because of these red beds the top of the plateau to the east is called the Painted Desert. The Kaibab limestone also caps the tableland to the west called Walhalla Plateau.

PLATE 92B

Northern part of Grand Canyon National Park and western wall near lower end of Marble Canyon.

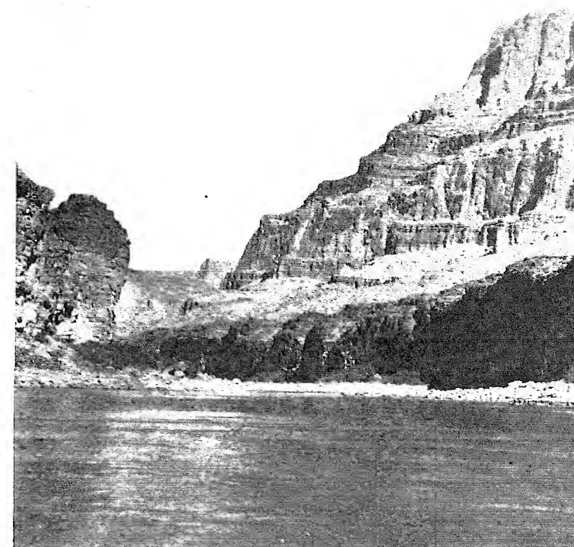
PLATE 93A AND B

NEAR MOUTH OF LITTLE COLORADO RIVER

At the lower end of Marble Canyon the layer of marble outcrops high in the wall and in places shows variegated laminations that persist for several miles. The color bands are of many shades. Below the marble and outcropping in the lower parts of the canyon walls are the evenly bedded rocks of the Tonto group. The walls rise to an altitude of about 6100 feet above sea-level or 3300 feet above the river. In some places this altitude is gained in a horizontal distance of about half a mile, the rise being accomplished by cliffs and slopes to the great platforms on either side of the river. At the right is a view of the eastern wall of the canyon just north of the mouth of Little Colorado River. The wall west of the river is somewhat broken. Through notches cut by tributary streams entering the canyon from the west, glimpses are obtained now and then of the cliffs of the high Walhalla Plateau and of the irregular pyramidal buttes. The Tonto group, 1050 to 1360 feet thick where measured west of Bright Angel, consists of Muav limestone above, Bright Angel shale in the middle, and Tapeats sandstone at the bottom. These rocks contrast sharply with those which characterize most of Marble Canyon. They are made up of many thin layers of rock which vary in hardness, so that the walls, instead of presenting smooth cliff-faces for long distances, have a rough surface and a horizontally banded appearance.

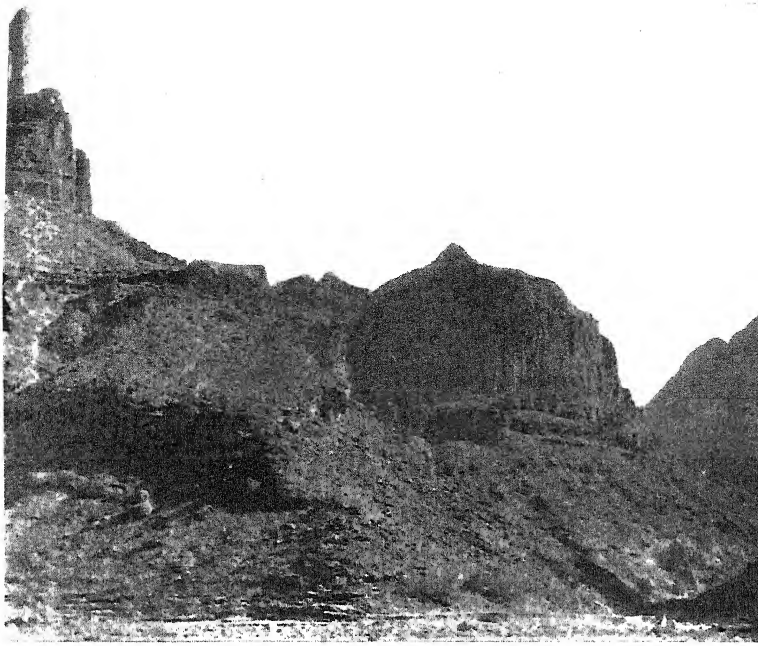
Plate 93

A



B

PLATE 94



A

PLATE 94A

Mouth of Little Colorado Canyon

A canyon on a scale almost as grand as that of the Colorado itself has been cut nearly through the horizontal rocks of the Painted Desert whose flat surface lies more than thirty-three hundred feet above the Colorado. The great cliffs at the rim of the canyon are formed by the Kaibab limestone, and those about one thousand feet above the river by the Redwall limestone. The mouth of the Little Colorado shown above on the opposite page is the center of a landscape whose magnificence and beauty make it worthy of a place among the remarkable landscapes of the Grand Canyon National Park. The river is variable in a number of ways. Sometimes there is so little water in the stream that it may be forded; at other times the canyon contains a forceful torrent. The Little Colorado drains about 25,900 square miles of lofty plateau country which lies high above sea-level. But in this semi-arid region the rainfall is only eight to twenty inches a year, and the average annual discharge is less than 200,000 acre-feet. That is, the whole flow for a year would cover 200,000 acres one foot deep. Much of this discharge results from short, violent showers causing sudden floods, which bring great quantities of sand and silt into the Colorado. Some of the rocks washed by these floods are red, some yellow, some gray. A shower over an area of red rocks makes a flood of red mud, one over yellow rocks a flood of yellow mud. Some observers have described the red water of the Little Colorado, others the slimy yellow water; still others, its limpid water. The observations were made at different times and doubtless all are correct.

PLATE 94B

Canyon Wall Near Mouth of the Little Colorado

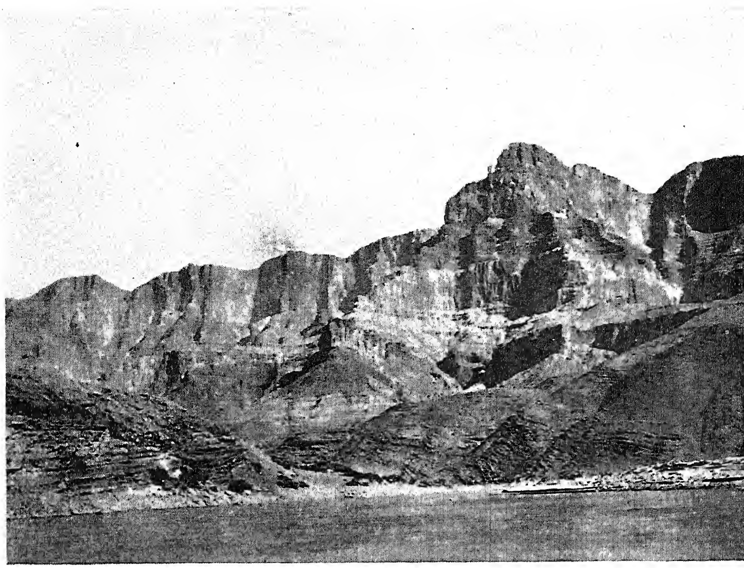
The Little Colorado is the arbitrary division between Marble Canyon and the Grand Canyon proper. There is little change in the character of the walls except that the older rocks which underlie the Tonto group here come to the surface. Above these are the rust-colored Tonto sandstones and conglomerates, some very hard, others soft, all lying nearly horizontal. The beds of softer material have been washed out, so that the harder beds form a series of shelves. Still higher is the massive layer of marble and the red Supai Formation, all leading up in magnificent succession to the great vertically-faced ledge of Coconino sandstone and Kaibab limestone which caps the promontory south of Little Colorado Canyon called Cape Solitude. In some places these rocks are broken and shelving for six hundred or seven hundred feet. Then there may be a terrace which can be climbed only where some gulch is found. Above these are other slopes, terraces, and cliffs.

PLATE 95A and B

Titan of Chasms

With a photograph such as that at the top of the opposite page one can better appreciate the scene viewed by Major Powell from the side of Cape Solitude. Here at the foot of the cliff which he could not scale, possibly the Redwall limestone, he looked off to the west, across the river, to a great plateau from which small streams run down into the Colorado, into deep gulches in the rugged and flaring escarpment opposite, set with cliffs and towering crags. He looked far up Marble Canyon to long lines of chocolate-colored cliffs, and above these, to the Vermilion Cliffs. He gazed up the Little Colorado through a very ragged and broken canyon, with sharp salients set out

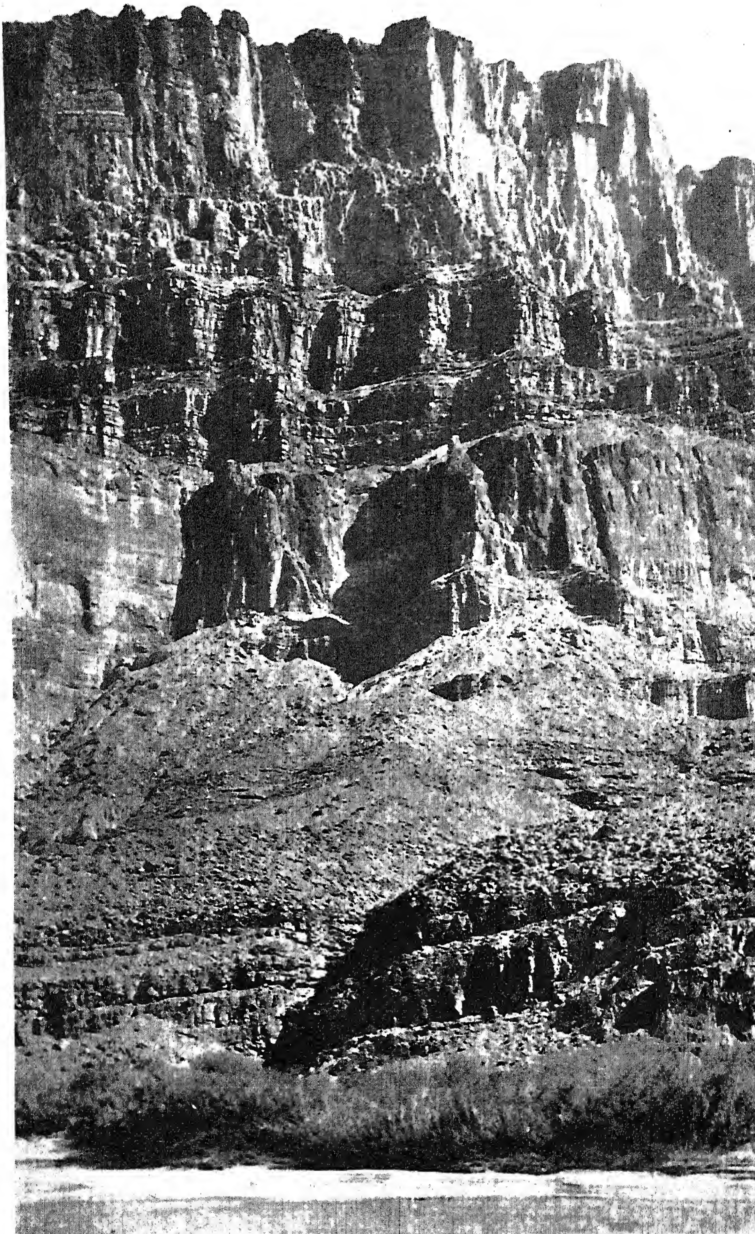
PLATE 95



A

B

Plate 96



from the walls on either side. Such a vista is unexcelled; and there is nothing equal to it except other scenes of the same nature in the Grand Canyon. In this "Titan of Chasms," which occupies an area about as large as the State of Maryland, there are many similar views.

PLATE 96

Below the Little Colorado

The rocks in the lower part of the walls for a considerable distance below the mouth of the Little Colorado belong to the Grand Canyon series. They were upturned and eroded in pre-Cambrian time to such an extent that the whole series many thousands of feet thick was eroded away in some places, and the upturned rocks beveled evenly so that the layers of the younger rocks, the Tonto group, extend across their beveled edges onto the still older crystalline rocks.

Here we are within the Grand Canyon proper, surrounded by the natural wonders that make it one of the marvels of the earth. It is really a continuation of Marble Canyon, but in it the river is even more tumultuous. From the mouth of the Little Colorado to Kanab Canyon, a distance of eighty-two miles, the fall is eight hundred and thirty feet, or an average of ten feet per mile. Below Kanab Canyon the average fall is less. Between this canyon and the Nevada line, a distance of 144 miles, the fall is about 1050 feet, or a little over seven feet per mile.

PLATE 97

View From Zuni Point

The photograph opposite presents a view of the eastern part of the Grand Canyon National Park. On the left is Walhalla Plateau, a part of Kaibab Plateau, terminating in Cape Final at CF. At the right in the background is the plateau east of the river known as the Painted Desert, PD, bordered by the Desert Façade, DF. In the far distance underneath the clouds is seen Echo Cliffs, EC, about forty miles away. At the right the mouth of Little Colorado Canyon, LC, may be distinguished and the Palisades of the Desert to the south of it. South of the Little Colorado is Cape Solitude, CS, one of the points famed for the magnificent view to be obtained there. In the distance is Chuar Butte, CH, Jupiter Temple, JT, Venus Temple, VT, and many other points of interest. In the middle distance is seen a small stretch of the Colorado River, CR. In the middle distance, too, the flat-lying Paleozoic rocks may be seen lying unconformably on the beveled edges of the inclined rocks of the Grand Canyon series. These ancient rocks have been uncovered over a wide area and because of their relatively uniform character they make mild topography. The rock formations are, K—Kaibab limestone, C—Coconino sandstone, S—Supai red beds, R—Redwall limestone, T—Tonto group, and UN—Unkar group.

Plate 97

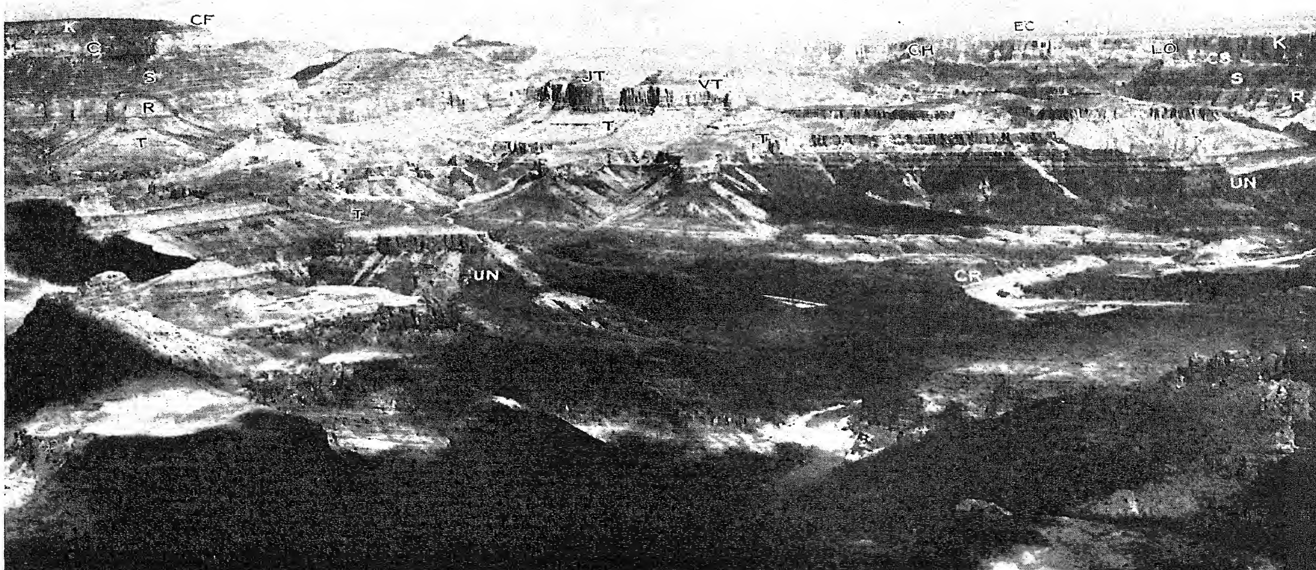
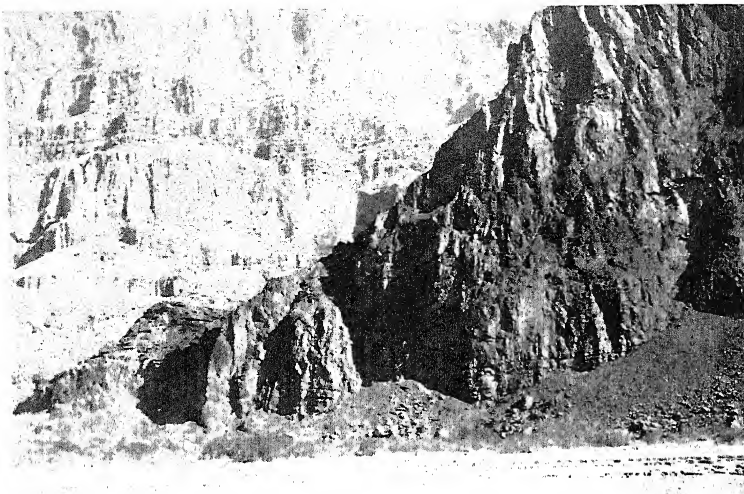


PLATE 98



A

B

PLATE 98A

PART OF A LARGE DIKE NORTH OF THE RIVER BELOW THE MOUTH OF THE LITTLE COLORADO

Near here we found a prospect hole and in it some provisions which had been left by the owner. From these a little was added to our store, as our supplies were very low and we could secure none until reaching Bright Angel.

PLATE 98B

BELOW RAPID NO. 7 IN THE GRAND CANYON

PLATE 99A

Wall of Grand Canyon at Rapid No. 8

PLATE 99B

A Fault in the Earth's Crust

A short distance from the mouth of the Little Colorado, the river crosses the line of one of the great faults of the plateau region where the earth's crust was broken and the rocks on one side of the fracture slipped past those on the other side. This is known as the Eastern Kaibab fault. This crack in the crust of the earth is said to be more than three hundred miles long and to have a maximum displacement or slip of about seven thousand feet. That is, where the slip is greatest, a stratum once continuous is "faulted" so that the part west of the fault line is found seven thousand feet higher than the part east of the line. As seen near the river the ancient rocks of the Chuar group which underlie the Tonto beds of Cambrian age have been lifted northwest of the line of displacement to such an extent that they have slipped past both the Tonto group and the Redwall limestone. This is graphically illustrated in the following profile section.

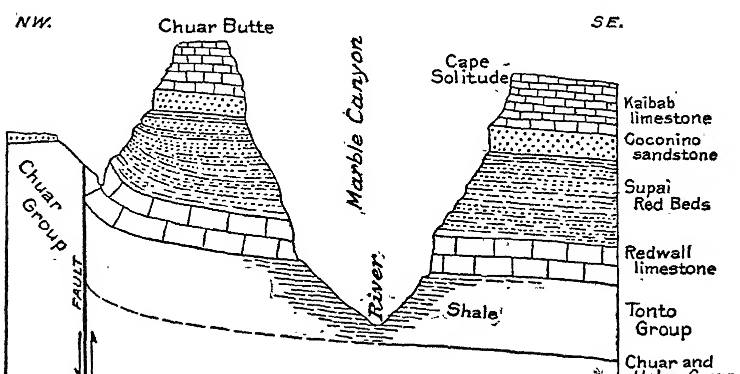
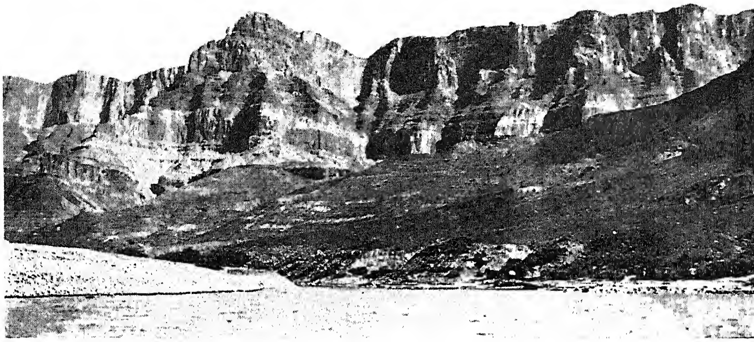
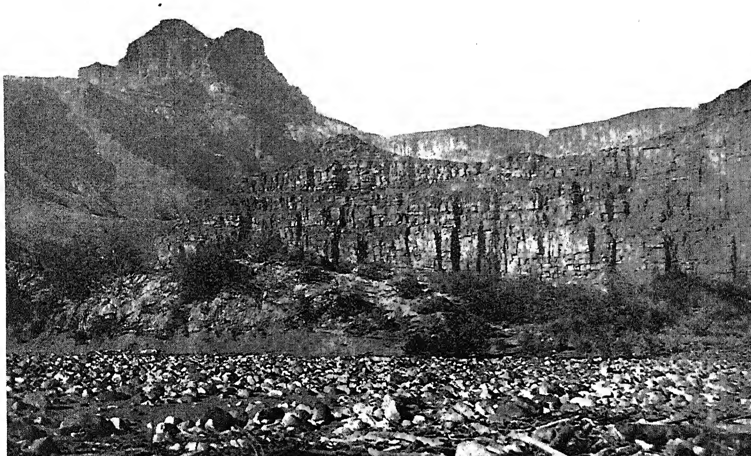


Fig. 6. Section Across Marble Canyon near the Mouth of the Little Colorado River. (After N. H. Darton.)



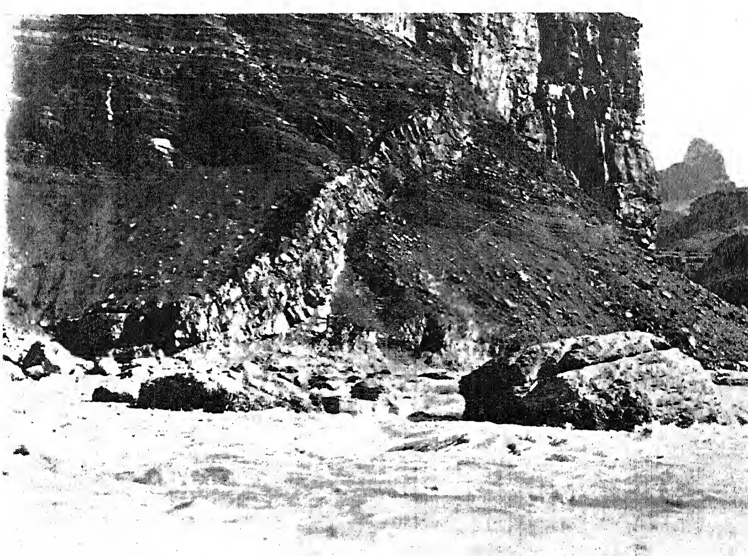
A



B

PLATE 100

A



B

PLATE 100A AND B

NEAR LAVA CANYON IN THE WESTERN PART OF GRAND CANYON

(A) A general view showing the high plateau in the distance.

(B) A near view of one of the dikes. About four miles south of the Little Colorado the river cuts through igneous rocks. Here is Lava Canyon and Lava Butte, names which bespeak the eruptive character of the rocks. The photograph opposite shows a dike of igneous rock cutting diagonally through the nearly horizontal layers of sedimentary strata. Some time in the unknown past a convulsion within the earth here cracked its crust and into this crack melted rock, seeking a way of escape, entered from some reservoir of unknown depth beneath the surface. When the extrusive force weakened and the intruding rock was no longer kept in motion, the molten matter in the crack hardened, and resisting erosion more effectively than the sedimentary rocks on either side, was left as an outstanding ridge in the canyon wall.

PLATE 101A AND B

THE UPPER END OF GRANITE GORGE

Here the crystalline rocks of Archean age appear under the sedimentary rocks of Algonkian age called the Grand Canyon series. The rocks of this series are somewhat mineralized. Many prospects have been opened. Copper, asbestos, and other minerals are found, but hardly in paying quantities. Spoil from some prospect holes may be seen on the bench just above the "granite."

PLATE 102A

UPPER GRANITE

A few miles above Red Canyon, the south side tributary of the Grand Canyon down which the old Hance trail runs, the river leaves the ancient sedimentary rocks of the Grand Canyon series and enters the still older rocks usually called Granite. They are known to geologists as the Vishnu group of rocks of Archean age, and consist of schist, gneiss, and granite, and a variety of crystalline matter in the form of dikes, sills, and veins. This so-called granite is the rock of Granite Gorge, or the Inner Gorge, as it is often called, rising several miles west of this locality to a maximum of about thirteen hundred feet above the river.

At the entrance to the "granite" the sudden change in the character and color of the walls is startling, especially so when considered in connection with the configuration of the portal, which is narrow and does not permit the eye to penetrate far because of a sudden turn of the river, giving the impression of a gateway to some forbidden land.

About three miles below the first appearance of the "granite," the walls of crystalline rock rise one thousand feet above the river and close in until at the water the canyon seems like a narrow trough between almost vertical walls, the fallen boulders making troublesome rapids. Here

A

B

Plate 102

B

is located the great rapid named Sockdologer. One who entered this rapid years ago thought it the most fearful place he had ever seen. Dellenbaugh gives the descent as eighty to one hundred feet and Thompson's diary as one hundred and thirty feet in three-quarters of a mile. We were not particularly impressed with it, and had no difficulty in running the rapid, nor in making a landing at the foot for observation. Our passage, however, was at a time of medium low water. We estimated the rapid to be one-third of a mile long, with a fall of thirty-four feet, but evidently we made an error, as Col. Birdseye, by actual survey, later found it to be about ten feet less. A different stage of water might account for some of the discrepancy. However, the survey showed we also were wrong in our estimate of its fall.

PLATE 102B

The Granite Gorge

The Granite Gorge is one of the notable features of Grand Canyon. Because of the uniformly hard rock and the steep gradient or slope of the river, the stream has cut a steep-walled gash which contrasts sharply with the broader upper portions of the canyon which have been worn out from rocks consisting of alternating hard and soft layers. Of this scene Dellenbaugh says: "About eight miles below Little Colorado we saw before us an enormous gorge very wide at the top which could engulf an ordinary mountain range and lose it within its vast depths and ramifications. Multitudinous lofty mesas, buttes, and pinnacles begin to appear, each a mighty mountain in itself, but more or less overwhelmed by the greater grandeur of the cyclopean environment." Had Virgil been in Granite Gorge we could better understand why he wrote "Facilis Averno descensus est; sed reddere." Certain is it that one who enters the depths of Granite Gorge by boat will not return the way he entered.

PLATE 103A AND B

Ragged Walls of the Inner Gorge

(A) A view down stream from a point below Sockdologer Rapid.

(B) Inspecting Rapid No. 26, the second rapid below Sockdologer. It is wild, but the channel is straight, hence more readily inspected than rapids in curved channels.

PLATE 104A

Near Bright Angel

The region about Bright Angel is the best known part of Grand Canyon. It is seen by more people than any other part. This is the heart of Grand Canyon National Park and is viewed by an increasing number of tourists each year. The physical factors here which make for remarkable scenery are shown graphically in the following profile section. If the reader will imagine himself looking at the

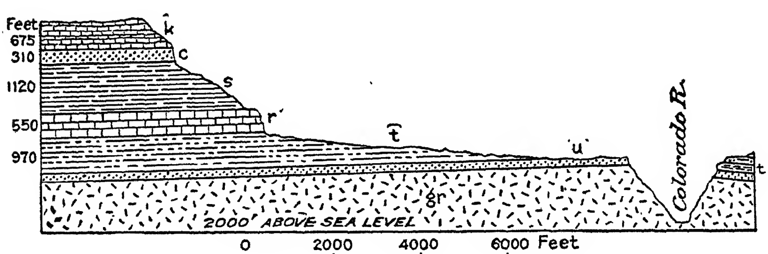


Fig. 7. Section in south wall of Grand Canyon at Grand Canyon Station, Arizona; k, Kaibab limestone; c, Coconino sandstone; s, Supai formation; r, Redwall limestone; t, Tonto group; u, Unkar group; gr, granite.

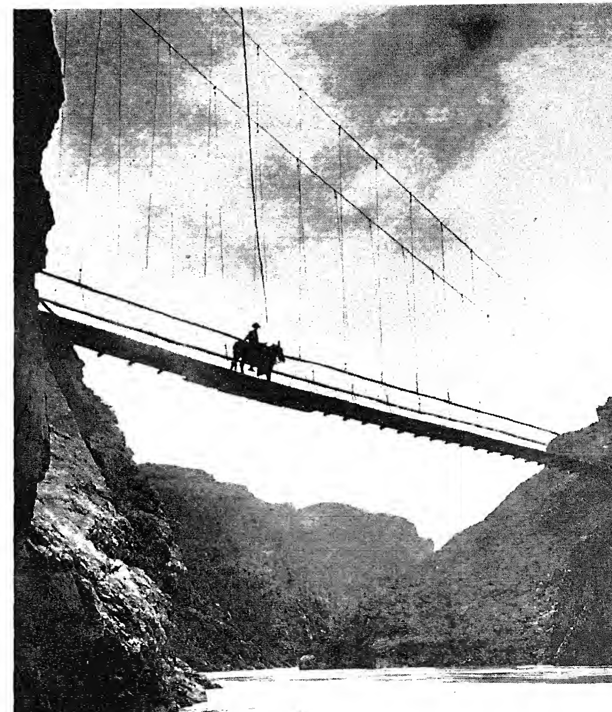
rocks as if cut at right angles to the canyon, he will see in the hard crystalline rocks a great V-shaped notch, the Granite Gorge, a broad shelf more than one thousand feet above the river called the Tonto Platform because it is eroded from the soft Tonto shale, and the outer escarp-

PLATE 103

A

B

Plate 104



ment, made up of the cliff-forming Redwall limestone, the brilliant red sandstone and shale of the Supai formation, the light colored cliff-making Coconino sandstone, and the hard rim rock called Kaibab limestone.

Scenes such as this impress those who behold them in various ways. Some are depressed and think it "the most awful, horrible place ever conceived of." Another refers to "its unspeakable sublimity." One exclaims, "Talk about holes in the ground!" and another reverently remarks, "Doubtless, God might have made something more wonderful, but doubtless He never did." Like a great soul in an unappreciative world, the Colorado runs its deep, silent, lonely course, too little understood, too little appreciated, loved by few, feared by many, and only a name to the multitudes who have never seen it.

PLATE 104B

Kaibab Suspension Bridge

(Photograph by National Park Service)

The suspension bridge shown in the photograph spans the Colorado near the foot of Bright Angel Trail. It is built for horseback travel, as no vehicles can approach the river. According to the National Park Service, it has a deck span of four hundred and twenty feet and measures five hundred feet between anchor bearings. It is suspended from two seven-eighth inch steel cables, the deck being fifty-six feet above low water and about thirteen feet above high water. The work was begun December 15, 1920, and completed May 15, 1921.

PLATE 105A AND B

TONTO PLATFORM NEAR BRIGHT ANGEL

(A) On the Rust Trail, showing the Tonto Platform in the middle ground and the steep wall of crystalline rock at the right below this platform.

(B) View from the Tonto Platform across the inner gorge to the north wall of the canyon.

PLATE 106A

A FAMILIAR SCENE FROM BRIGHT ANGEL TRAIL

The photograph above on this plate, shown through the courtesy of N. W. Carkhuff of the United States Geological Survey, presents a view across Granite Gorge looking up Bright Angel Canyon, showing Buddha Temple to left and Brahma Temple to the right. In the foreground and in the opposite wall of the inner gorge the ancient granite and gneiss of Archean age appear. Above the Archean crystallines are the basal limestone and conglomerate of the Unkar group. These beds are contorted at

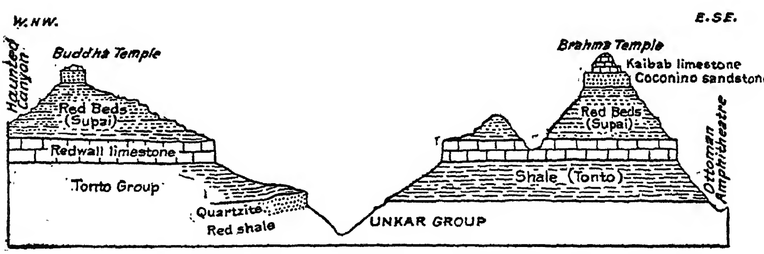
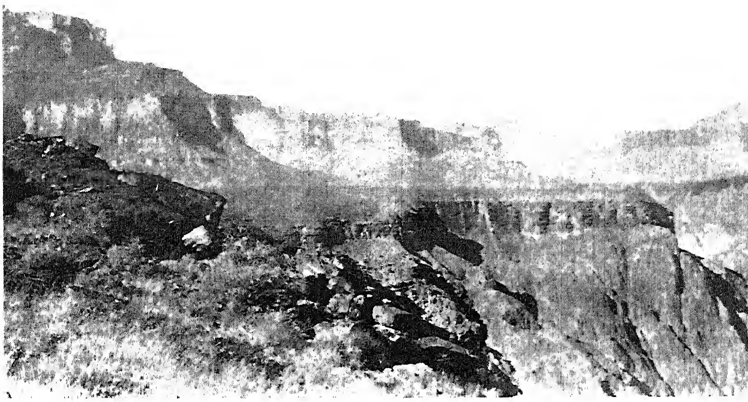


FIG. 8. A profile section across Bright Angel Canyon from Buddha Temple to Brahma Temple. (After N. H. Darton.)

a fault line shown in the center of the photograph. Above these basal beds are the red shale and red quartzite of the Unkar group, the basal sandstone of the Tonto group, and in the distance the Redwall limestone, the Coconino sandstone, and the Kaibab limestone.

PLATE 105



A

B

PLATE 106

A

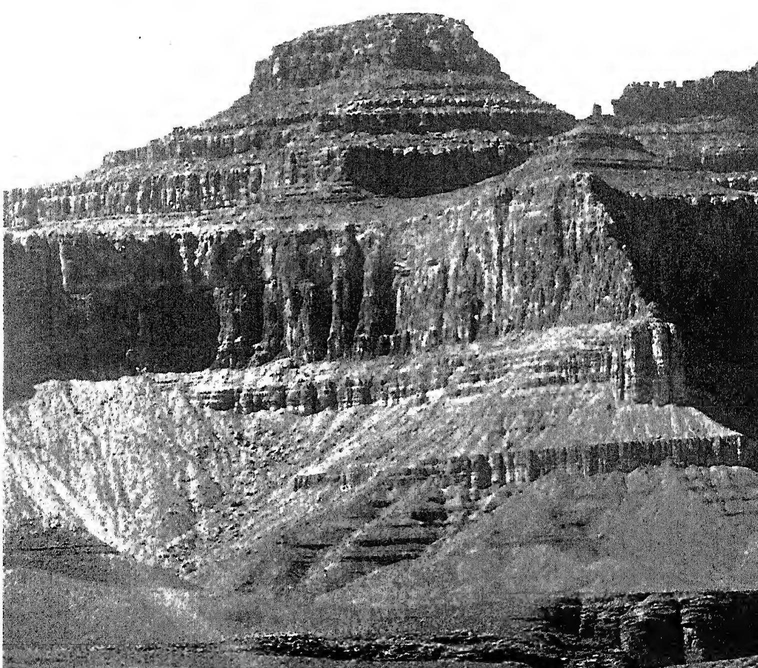


PLATE 106B

As Seen Through a Glass

The great distance from rim to rim of the canyon renders possible the comprehensive views which impress so many with the thought that this is the Canyon Wonderful. But there is another side to be considered. The clear Arizona atmosphere makes it possible by the use of field glasses to secure almost any amount of detail desired. Scores of views such as that on the opposite page may be had from any commanding point on the canyon rim or within the gorge, and by use of a telephoto lens photographs showing as many details as this one taken from the Bright Angel Trail may be obtained. The chief features in this view are the Tonto Platform, shown as a relatively even surface in the foreground formed on the hard sandstone, the step-like slope formed at the outcrop of the Tonto group partly covered with talus or loose fragments of rock, and the precipitous ragged cliff of Redwall limestone, above which are the evenly bedded sandstones and shales of the Supai red beds.

PLATE 107A

Red Butte Near Bright Angel Trail

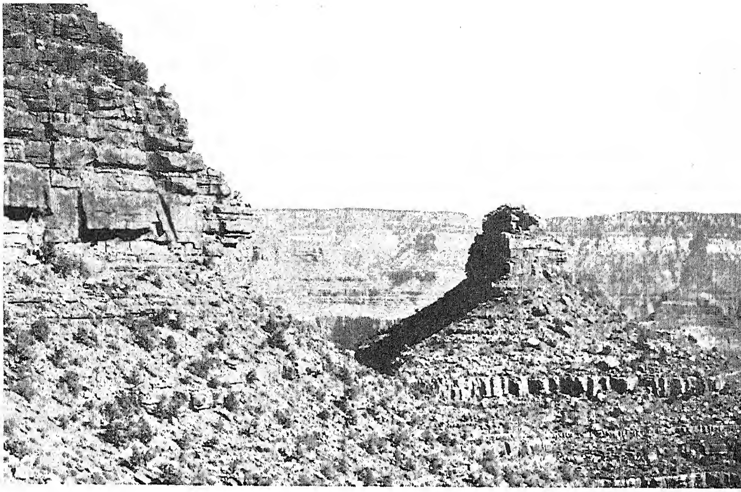
The near view of one of the small land forms of the canyon shown above gives some idea of the character of the beds of red sandstones and shales which were piled layer on layer to make the plateau. In the distance the wall on the far side of the canyon, made up of Redwall limestone below, red strata of the Supai formation above, Coconino sandstone and Kaibab limestone at the top, has hundreds of similar buttes, but viewed from a distance they seem to blend and give the impression of a straight and relatively smooth wall. Just below the sky line is a narrow, light-colored band in the canyon wall. This marks the position of the cliff of light-colored rock known to geologists as the Coconino sandstone.

PLATE 107B

A Near View of the Coconino Sandstone

Observers who approach close to the Coconino sandstone, as all do who use the Bright Angel Trail, may notice certain diagonal striations and a number of irregularities in the beds of sand which constitute the great cliff. One group of beds may be inclined in one direction and another in a different direction. This is known as cross-bedding. The irregularity in stratification was produced when the sandstone was deposited here long ages ago. Similar irregularities are produced at the present time where sand is accumulating in running water, and in sand dunes where the material is shifted by changing winds.

PLATE 107



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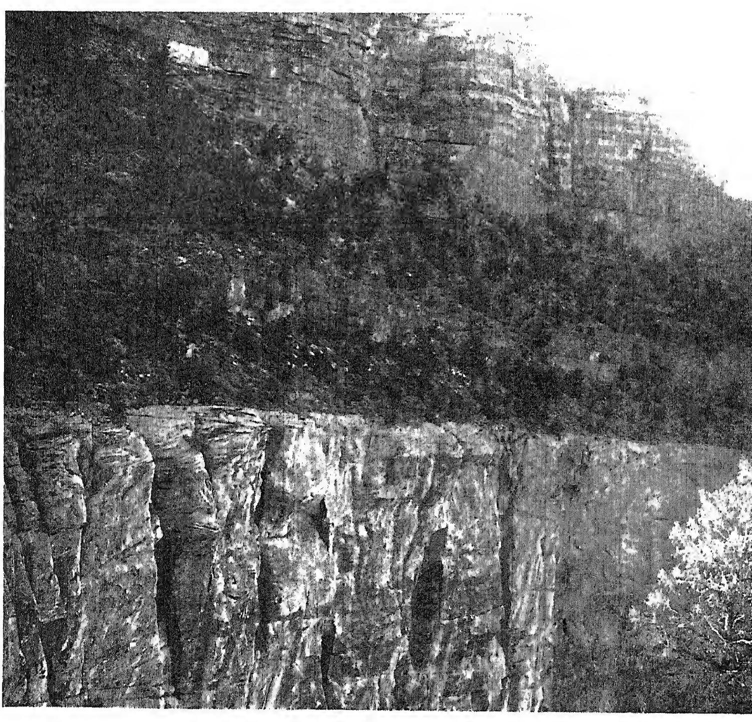

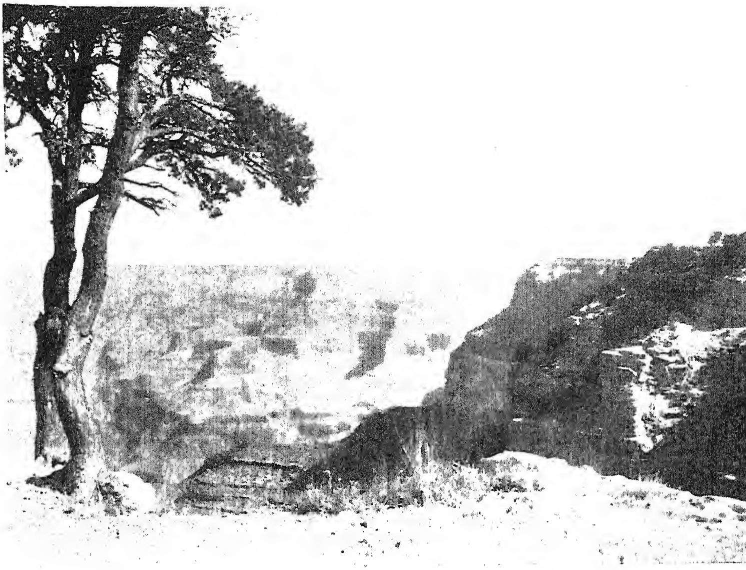

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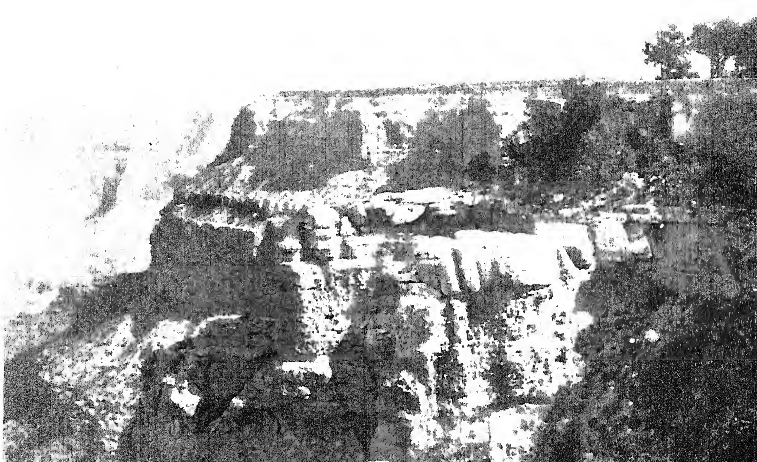


B

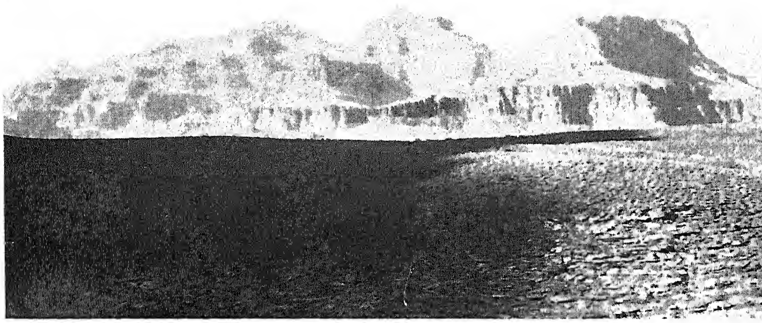
PLATE 108A AND B

RIM OF THE GRAND CANYON AT BRIGHT ANGEL

(A) Looking across the Grand Canyon from the south rim. Bright Angel Canyon appears at the right of the trees.
(B) A part of the south rim from the same point.

PLATE 109A AND B

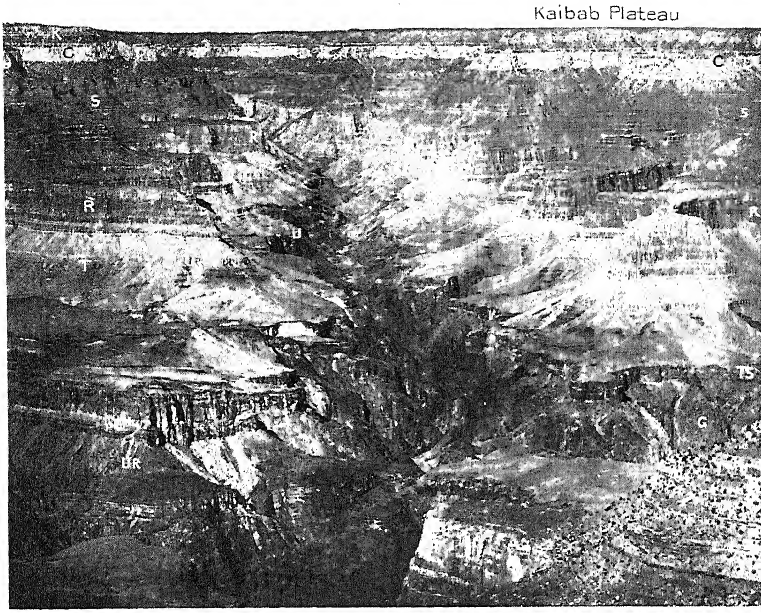
SCENES FROM BRIGHT ANGEL TRAIL



A

B

Plate 110



A

B

PLATE 110A

Looking up Bright Angel Canyon from the South Rim of the Grand Canyon

The Colorado River is at the foot of the cliffs in the foreground of the photograph at the top on the opposite page, deep in the Granite Gorge below the line of vision. The cliffs marked *U* are formed by the ancient strata of the Unkar group and the ragged slopes below them represent the Archean granite and schist. On the softer rocks of the Tonto group are formed the relatively smooth slopes marked *T*. *R* is the great cliff-making Redwall limestone, and *C* the Coconino sandstone. The Kaibab limestone, *K*, inconspicuous here because far away, caps the Kaibab Plateau whose nearly level surface appears in the distance. This region furnishes one of the most complete and perfectly exposed successions of stratified rock to be found anywhere in the world. It exhibits thick layers of rocks of various kinds and ages, some of them tilted at different angles, and it illustrates most clearly the origin of many types of land forms on a titanic scale. Since the completion of the suspension bridge which now spans the river at the foot of Bright Angel Trail, the wonders of this tributary of Grand Canyon are available for the inspection of the traveler who is hardy enough to endure the thirty mile trip from El Tovar to the Wylie Camp on Bright Angel Point. This stream heads away back under the line of abrupt cliffs that terminate the plateau, and tumbles down more than four thousand feet in its course to the Colorado. The way up the Bright Angel Gorge on the north side is somewhat difficult. The mules ford the creek eighty-odd times. This may be no great hardship in favorable weather, but a sudden shower might easily make the fords temporarily impassable.

PLATE 110B

Boating and Rapids

Everyone agrees that below Bright Angel the rapids are particularly bad. Difficulty here encountered at the bottom of the narrow Inner Gorge makes the freedom of the cloudy realm above seem wonderfully attractive. Forty years before our coming, imprisoned between one-thousand-foot walls of granite crags, Powell had observed, "Down these grand, gloomy depths we glide, ever listening, for the mad waters keep up their roar. . . . We listen for falls and watch for rocks, . . . and ever, as we go, there is some new pinnacle or tower, some crag or peak, some distant view of the upper plateau, some strange shaped rock, or some deep, narrow side canyon, . . . and now we go on through this solemn, mysterious way. The river is very deep, the canyon very narrow and obstructed so that there is no steady flow of the stream; but the waters whirl and roll and boil, and we are scarcely able to determine where we can go."

Granite Gorge will never be forgotten by anyone who has gone through its turbulent aisles. As seen from the depths, the canyon appears full of overawing immensities.

PLATE 111A and B

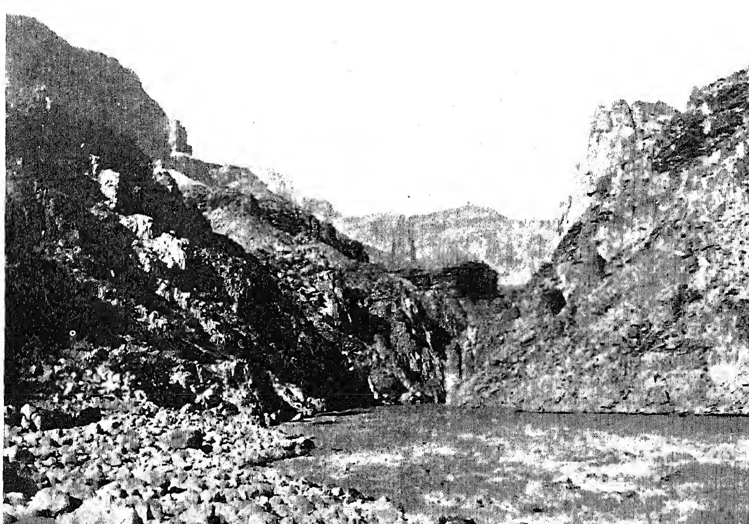
An Inner Gorge

In the upper photograph on the opposite page the sedimentary rocks appear in horizontal position above the crystalline rocks, just as they were laid down on the Pre-Cambrian plain long ages ago before the river cut its gorge.

In the photograph below a more distant view is shown, and the strata far in the distance, although nearly horizontal, appear to be tilted, because the observer is looking up at them.

PLATE III

A



B

PLATE 112

A

B

PLATE 112A

Granite Ledge Rapid

The rapids in this part of the canyon make boating a serious matter. Hermit Creek also proved to be a bad one and its passage was fraught with some difficulty. It is not surprising that traveling over a route like that shown in the photograph at the top of the opposite page, in a narrow trench more than a mile beneath the general surface of the country, we, like others, should have become impatient and wished to reach the end of its imprisoning granite walls. Their monotony became anything but enjoyable. At the last rapid in Conquistador Aisle we met with some trouble and one boat was overturned, but no serious damage resulted.

PLATE 112B

The Oldest Rocks in the World

At the left in the lower photograph opposite is a bed of sand deposited during some flood and cut by the subsiding waters into a beautiful series of terraces. Beyond this bed rise walls of the crystalline rocks of Granite Gorge. The rocks through which the river here makes its devious way are the ancient crystallines supposed by some to be parts of the original crust of the earth as it came from the hand of its Maker in the beginning. Others think these rocks differ from the stratified rocks which overlie them only in degree of metamorphism. That is, they may once have been sedimentary rocks like those higher in the walls, but have been so long buried deeply beneath younger rocks and subjected to heat and pressure that they have become completely recrystallized and are no longer recognizable as being of sedimentary origin. They possibly belong to the oldest system of rocks recognized by geologists. Here they took their place countless ages ago when the surface of the earth was waste and void and even more nearly barren

and lifeless than these canyon walls appear now. Here they have remained since the rocks responded to the command "Let the earth put forth grass"; and here they have lain since a day long antedating the first appearance of life and through the unthinkable eons during which it rose from the clod and the "polyp struggled up to man."

PLATE 113

View from Grand Scenic Divide

This photograph taken by N. W. Carkhuff from the Esplanade under Havasupai Point is a view up stream toward the southeast, between Shiva Temple and Coconino Plateau. The rock formations and some of the points of interest shown in the photograph are designated as follows: P S, End of Point Sublime, M A, Monadnock Amphitheater; V, Vishnu schist; U, Unkar group; T, Tapeats sandstone; B A, Bright Angel shale; M, Muav limestone; R, Redwall limestone; Ss, sandstone of Supai formation; Ssh, shale of Supai formation; C, Coconino sandstone.

The conspicuous shelf on either side of Granite Gorge is the Tonto Platform. The rocks in the gorge below this shelf are the ancient crystallines and are here shot through with mineral veins which in angular form somewhat resemble forked lightning. The mineral of the veins is lighter colored than the rock containing them, and appears white in the photograph. Some place down deep in this narrow trench below the line of vision flows the Colorado, and above the Tonto Platform rise the great buttes and temples like colonnades from an esplanade. The author who wrote of the granite's "massive solidity on which to base miles of statuary" must have visualized the Grand Scenic Divide.

Plate 113

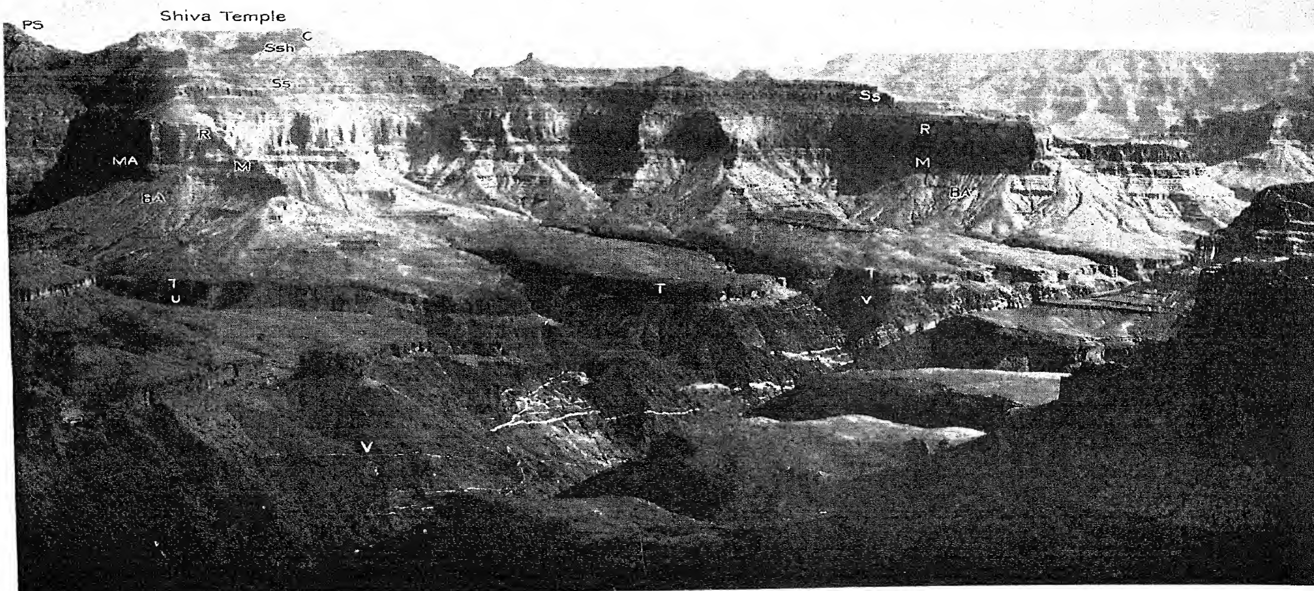


Plate 114

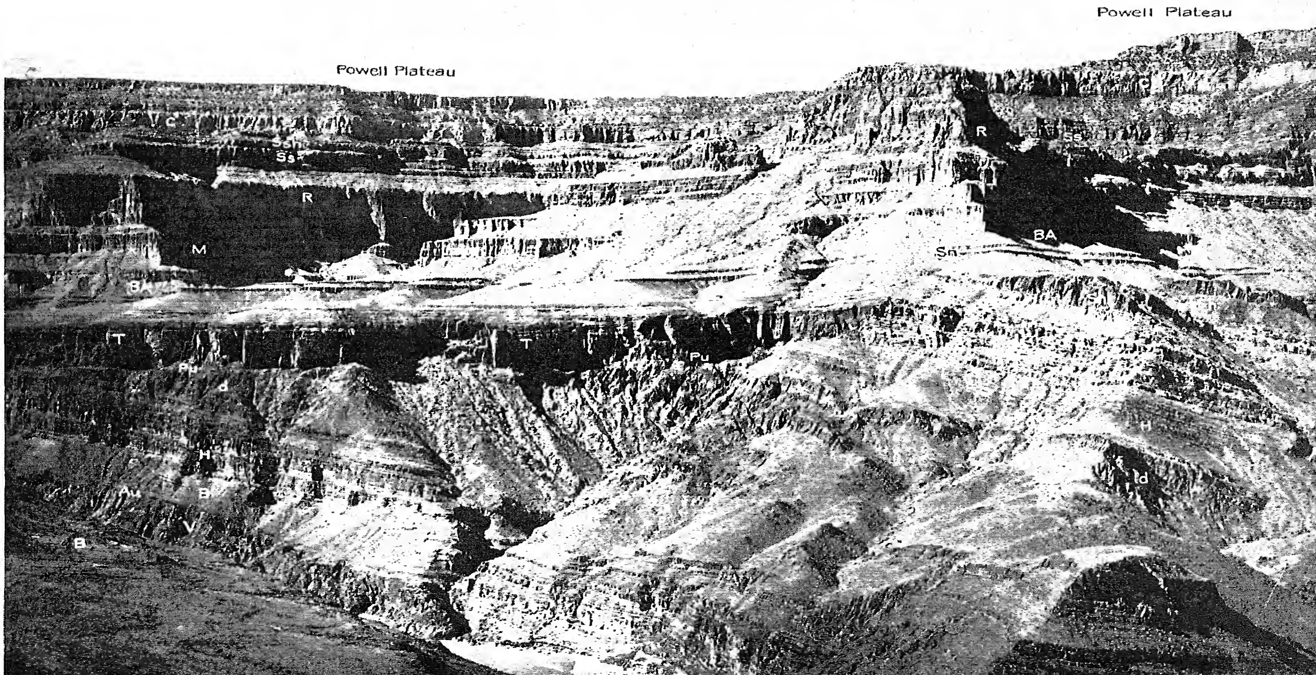


PLATE 114

Where Mountains Once Stood

This photograph taken by N. W. Carkhuff of the U. S. Geological Survey shows many of the significant features of the Grand Canyon. These are designated as follows: V; Vishnu schist; Au, Unconformity, separating the Archean and the Algonkian systems; B, Bass limestone; H, Hakatai shale; D, Diabase (intrusive); Sh, Shinumo quartzite; Pu, Paleozoic unconformity, separating Algonkian and Paleozoic rocks; T, Tapeats sandstone; B A, Bright Angel shale; Sn, "Snuffy limestone" in Bright Angel shale; M, Muav limestone; R, Redwall limestone; Ss, sandstone of Supai formation; Ssh, shale of Supai formation; C, Coconino sandstone; K, Kaibab limestone. A vertical mile of strata is in view.

The layers of rock which appear in the photograph on the opposite page are seen inclined toward the right, and are the very ancient sediments laid down in a horizontal position during Algonkian time, a period which may have closed some hundred millions of years ago. These strata were built up layer on layer and group on group until a thickness of more than twelve thousand feet of sand, mud, and limy ooze had accumulated. On inspection of the photograph it is evident that these tilted beds of the Unkar formation were partly eroded away so that they thin toward the left in what is technically known as the Unkar wedge. On

this surface lie the rocks of Paleozoic age, making a contact known to geologists as an unconformity. Here is the evidence of a long period of unrecorded time. After the Algonkian sediments had hardened into rock, some convulsion within the earth pushed up a great mountain wrinkle, if one may judge from the thickness of the rocks affected, more than twelve thousand feet high, a range comparable in altitude to the present Rocky Mountains. Then the storms and the frosts came, and tore the rocks apart until that range was removed and cast into the sea in the same manner that mountains are now in the process of removal. However, one small hill a few hundred feet high was left and when sediments again accumulated in this region the hill was buried, as shown in the photograph to the right.

This is only one of the many episodes of earth history to be read from these rocks for it has truthfully been said that "the Grand Canyon is the most instructive exposition of geology in the world." In reading over the various attempts of writers to portray the "ineffable beauty," the "marvelous grandeur," the "sublimity," and the "inexpressible qualities" of the canyon, one senses the futile struggle for unusual expressions and for terms adequate to the subject at hand. In some the expressions are far-fetched, silly, and maudlin; in others the authors make an honest effort to express their genuine emotion, realizing that no adequate words are available. One method of expression has found vent in Oriental names. Much criticism has arisen over these names on the ground that they belittle the great structural forms of the canyon. The real Cheops Pyramid would sink into insignificance beside its namesake in Grand Canyon; and Isis Temple might be lost in one of the recesses of the butte of the same name. Others defend these names on the ground that the nomenclature of the poetic and imaginative East is appropriate to voice in some measure that which cannot be adequately expressed. And indeed as there are qualities beyond the reach of the tape line and the surveyor's transit, useful as these instruments may be, so too only to the poet's vision may some of the qualities of the Grand Canyon be revealed. By poetry men seek to express that which

is intangible, which is beyond finite reach. "The Battleship" may seem appropriate as the name of a butte near at hand and easily reached, but for the great, ornately carved, and gorgeously decorated structures which may not be readily reached and which to most people must remain distant, unattainable and shrouded in mystery, such names as the Tower of Ra, Buddha Temple, Cheops Pyramid, Zoroaster Temple, Haunted Canyon, and Dragon Head seem pleasingly appropriate.

*

PLATE 115A

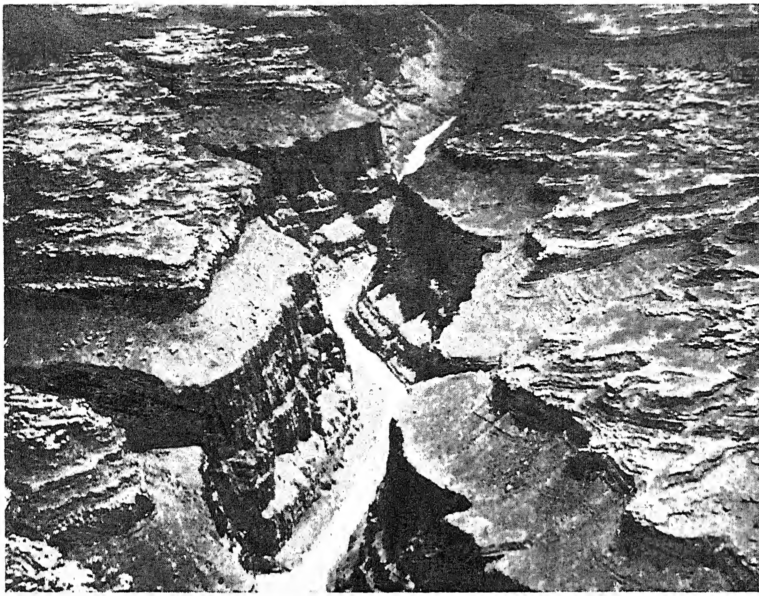
An Airplane View

The photograph opposite was taken from an airplane six thousand feet above the river. It was taken in 1921 by Mr. H. H. Bullen of Denver, Colorado, and is here reproduced by courtesy of the National Park Service. The observer in an airplane has the great advantage of being able to obtain comprehensive and unobstructed views. Air photographs are not marred by the exaggerated appearance of unimportant details in the foreground. This is somewhat out of place but that fact is of small consequence.

PLATE 115B

"The Chasm of the Colorado," by Thomas Moran

The artistic qualities exhibited by the Grand Canyon as a landscape have given rise to sharp differences of opinion. The immensity of the subject and the infinite variety of detail have induced many to claim that the best of paintings fall far short of doing justice to the unique scenery. On the other hand, the claim is advanced that the Grand Canyon presents an ideal toward which the artist may strive. Thomas Moran held the latter view. In pointing out that landscape painters too often select subjects of little consequence, he asserted that the Grand Canyon offers a new and comparatively untrodden field for pictorial interpretation, and only awaits the men of original thoughts and ideas who shall prove to their countrymen that we possess a land of incomparable beauty and grandeur.



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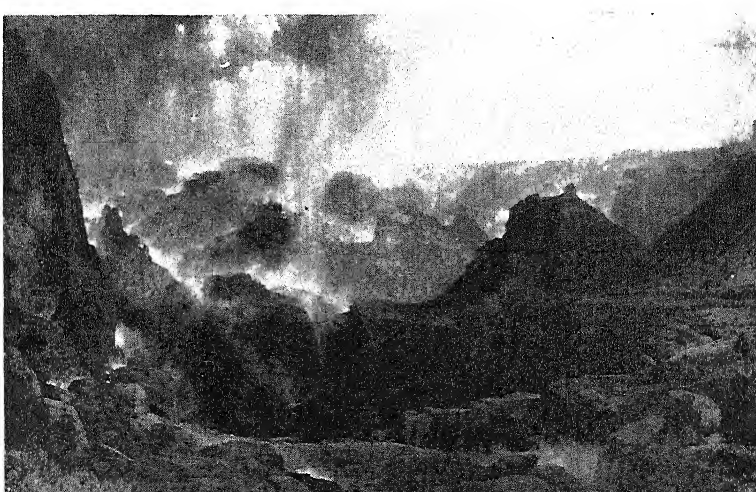

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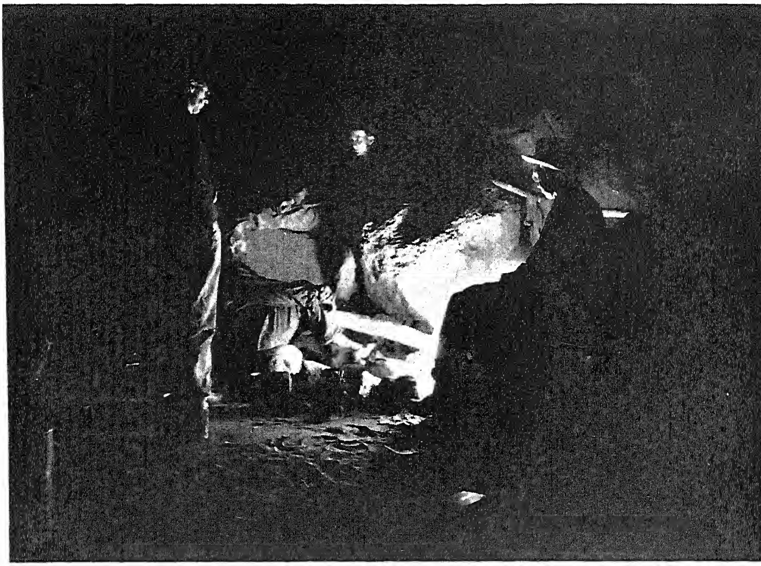


A

B

PLATE 116A AND B

Camp Sites in Grand Canyon

Wind-blown sand caught in the shelter of some boulder makes a camp site far superior to one composed of jagged rocks. Good camp sites are rare in a gorge like that shown in the lower photograph opposite.

PLATE 117A

Ancient Sedimentaries Capping the Granite Wall

What may be said of a wall like this, towering one thousand feet above the river? The superstitious Indians look upon the canyon as bad medicine, and even some white men consider it a place of mystery. Between such walls run the waste waters of 244,000 square miles of mountains and plateaus, an area nearly as large as Minnesota, Wisconsin, Iowa, Illinois, and Missouri combined. No wonder the river, rough in its mildest moods, during flood time is a fiend incarnate. The flood waters pile up in the narrow gorge and leave the record of their might on the walls. The parallel lines near the bottom of the photograph are so-called water lines or flood lines. Ordinary floods occur repeatedly and have marked the walls plainly. Extraordinarily high waters have left dimmer records in faint high lines. The height of floods is determined to some extent by boulders obstructing the stream. In the photograph to the left on this plate a few thousand tons of boulders have found their way through the notch in the rim and down the little gulch, into the river. The great river has little trouble in disposing of these, but at the foot of some of the larger gulches great boulder deltas partially dam the river.

The transporting power of running water varies practically as the sixth power of the velocity. Therefore if a stream doubles its rate of flow its transporting power is increased sixty-four times ($2^6 = 64$); if its velocity is trebled

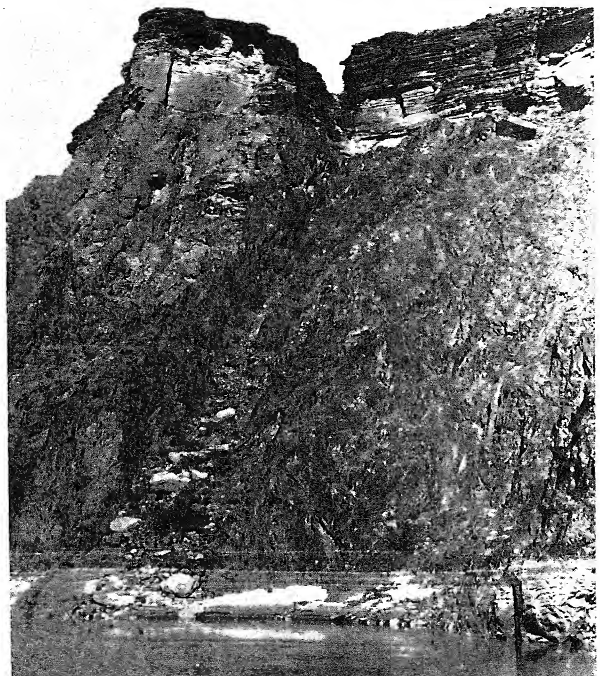
it can move masses seven hundred and twenty-nine times as heavy ($3^6 = 729$); and at four times its velocity this becomes four thousand and ninety-six ($4^6 = 4096$). The average specific gravity of surface rock is about two and one-half times that of water, but as this rocky material is submerged two-fifths of its weight is removed. Then, too, since at flood time the increment to the velocity of a stream is greater than the increment to its volume, it is easy to understand how flood waters can exert such tremendous and otherwise incomprehensible force.

PLATE 117B

In the Depths

Many have gazed in awe and wonder on gloomy depths such as that pictured at the right on the opposite page, but few have known the thrill of standing where this picture was taken and looking upward through the shadowy notches to the canyon rim a vertical mile above. Here the barren rock may be brilliantly lighted where the sun's rays fall, while twilight reigns in the shadowy recesses of the walls and in some of the tributary gorges where the full light of day is scarcely known. The traveler on the brink may gaze from afar and be overwhelmed with the sublimity of massive forms. But the traveler in the gorges stands among them and of them, becoming, through fair companionship, part and parcel of the incomprehensible whole. And why not, since the atoms that compose the surging waters, that wander hither and thither in the air and that seem so fixed in the solid rocks, are identical with those that course through our arteries with every pulsation of our restless hearts, also with those that build and maintain our bones, and that give us the house in which we live and have our being. In reality we are twin brothers to the rocks! When this thought was suggested to one of our party he remarked that, considering the difficulties we were meeting, our journey might be termed a somewhat extended family row.

Plate 117



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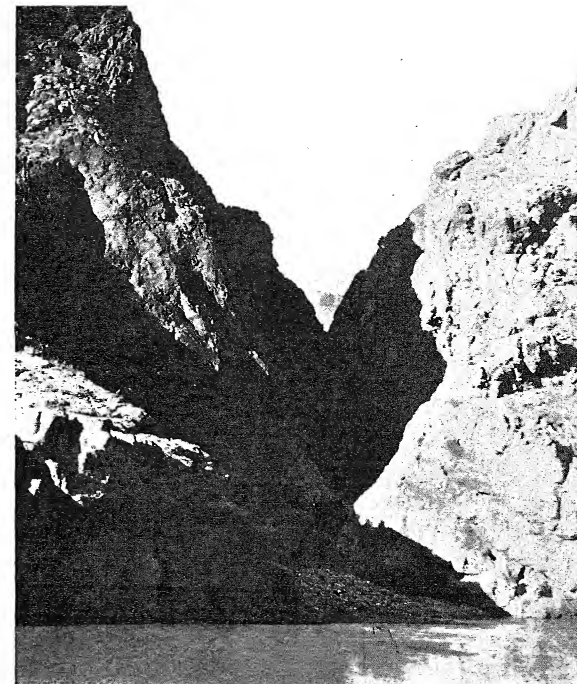


B

PLATE 118

A

B

PLATE 118A

How the Canyon Was Made

A tourist stood on the brink of the Grand Canyon and gazed a mile down into the depths. He saw the brilliantly colored spires and castellated forms that beggar description, and finally at their base, what looked to him like a tiny rill. He wondered how it all happened. One of his fellow tourists ventured the opinion that the canyon was formed by some great convulsion of nature, during which the rocks were split asunder, but a wiser observer pointed to the rock-bound stream at the bottom and remarked that the canyon is a product of the stream. The first argued that the river is not perceptibly deepening its canyon, and the second observer replied that no more do the hands of a clock *perceptibly* move. Although no measurable change may take place during a man's lifetime, the river is working now just as it has worked without a moment's interruption for untold ages. Particles of mud and grains of sand, pebbles and boulders are carried in endless procession down its tumultuous course, and every grain does its part toward cutting away the rocks. Some are contented with the enigmatic statement that the canyon was "gnawed out by the tooth of Time." Others are interested in knowing that the teeth which do this gnawing are the grains of sand set in the jaws of every flood.

PLATE 118B

Ancient Rocks

South of Powell Plateau, which perpetuates the name of the leader of the expedition which first explored this canyon, the granite of the canyon walls sinks below the level of the river, and its place is occupied by a great variety of rocks. Near the bottom of the canyon are the ancient sedimentaries of the Grand Canyon series. These have undergone great changes. They have been broken and faulted and crushed.

Into them, in some places, igneous rock has found its way, and in other places vein material has accumulated. However, the great layers of limestone and sandstone of the upper part of the walls continue undisturbed over this complicated mass of disturbed rocks. After the ancient Algonkian strata had been upturned, fractured, and invaded by igneous rock, they were worn down by erosion to a level surface on which the material of the Paleozoic rocks was laid down. One of the results of it all is shown in the lower photograph on this plate.

PLATE 119A AND B

(A) Near Shinumo Creek.

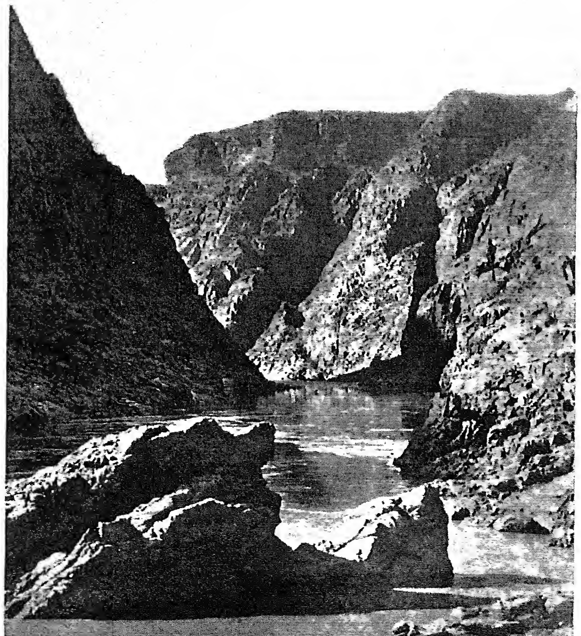
(B) View toward the north from a point just above Rapid No. 74.

Plate 119

A

B

Plate 120



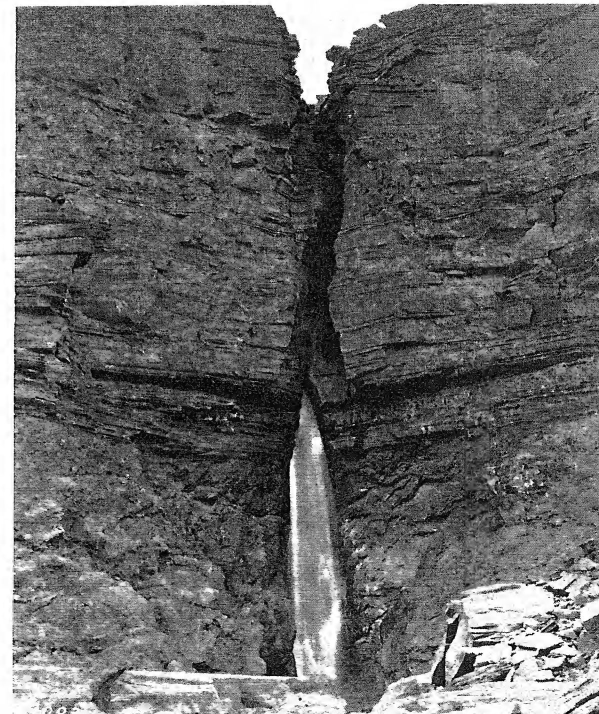


PLATE 120A

THE GRANITE PRISON

The few men who have recorded their experience in the Inner Gorge emphasize the depressing effect that the dark, forbidding walls had upon them. On entering the lower granite area Powell writes of his anxiety at again encountering the "dreaded rock" of these black, hard walls. The difficulties which followed justified his anxiety, and *may* have been among the reasons which he says influenced three of his companions to leave the party.

PLATE 120B

SURPRISE VALLEY

Surprise Valley joins Grand Canyon several miles up the river from Kanab Canyon. Among the surprises here, as in several other places in the lower canyon, are streams of water issuing from the walls as if from some huge pipe. Some of these originate as surface streams and have sawed narrow slits or miniature canyons down deep into the rocks. But as they were not strong enough to cut their little channels as rapidly as the mighty river deepened its bed, they were left as hanging streams. Other streams issuing from the walls originate underground. Some are springs of ordinary type, others are extraordinary in the sense that they represent the drainage of fissures or great cracks in the

rocks, others mark the openings of caves, and still others originated long after the main gorge was cut. In all probability the stream here shown belongs to this latter class. Comparison of this photograph with one taken at the same place by the Powell expedition shows that the stream has cut its notch perceptibly deeper during the intervening forty years.

PLATE 121

Views Near Kanab Canyon

A. Gorge in sedimentary rocks.

The photograph in the upper left hand corner on Plate 121 was taken by R. T. Evans, of the United States Geological Survey, from the rim of the Grand Canyon, opposite the mouth of Kanab Creek in a westerly direction toward Mt. Sinyalla, a butte of erosion left standing while the parent cliff at the left has receded about two miles. The rock formations range from Tapeats sandstone at the bottom to Coconino sandstone at the top. The chief cliff-maker is Redwall limestone. The inner gorge at this point is thirteen hundred feet deep and fifteen hundred feet wide at the top of the main cliff in the foreground.

B. Mt. Sinyalla.

The butte shown in the upper right hand corner is capped with Coconino sandstone. The sloping sides at its base consist of talus or fragments of this sandstone which have fallen from the wall above. The platform on which it rests is called the Esplanade. The view is toward the northeast across the canyon of Havasu Creek (formerly called Cataract Creek Canyon).

C. "Stone Babies."

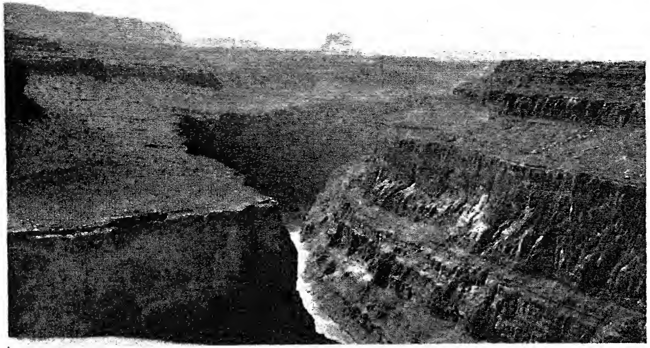
The photograph in the lower left hand corner was taken south of the canyon opposite the mouth of Kanab Wash. These monuments carved by erosion from the red sandstone of the Supai formation are representative of thousands of similar forms which some of the Indians call "stone babies." These curious freaks of erosion are scattered widely over the Esplanade. Kanab Plateau appears in the distance. Although no hint of its presence appears in this photograph the Colorado River flows between this plateau and the stone babies, more than two thousand feet below the surface shown in the foreground.

D. Havasu Valley.

In the lower right hand corner is a view of the Indian village in Havasu Canyon about eight miles from the Colorado River into which Havasu Creek empties. The valley here is about a quarter of a mile wide and is confined between red walls of the Supai formation which rise one thousand feet or more above the valley floor. The Indians' account of the origin of their settlement has been described as follows:

"When the several families, or bands of people, who afterward became the great tribes of the southwest, left their sacred canyon (Mat-a-we-dit-ta) by direction of their Moses (Ka-that-ka-ná-vé) to find new homes, the Havasupai family journeyed eastward on the trail taken by the Navajo and the Hopi. One night they camped in Cataract Creek Canyon, and early on the morrow took up their burdens to proceed on their journey, but just as they were starting a little child of the party began to cry, and the Kohot of the family, knowing this to be a warning from the Great Spirit, decided to remain and live in the Canyon."

They found a fertile valley of some five hundred acres of level land which was easily irrigated from the creek that bursts clear and sparkling from a thousand springs at the base of the great cliffs, and rushes on, over successive cataracts, to join the Rio Colorado in its vast canyon. They called the place Ha-va-sua, meaning Blue Water. And by and by they themselves were known as Ha-va-sua-pai, dwellers by the Blue Water, which rather pretty sounding name has in some unaccountable way become corrupted into "Hava Supai," "Supai," and "Suppai" by the whites who have attempted to use the Indian name.



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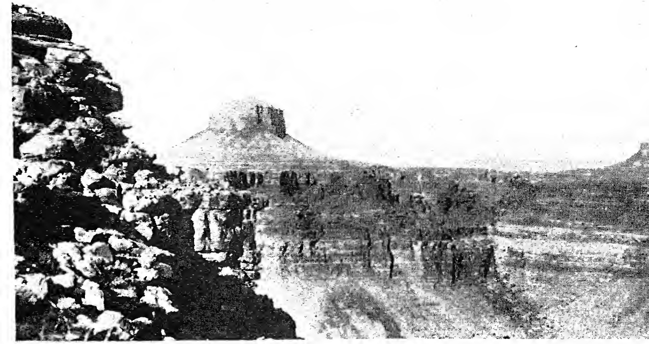

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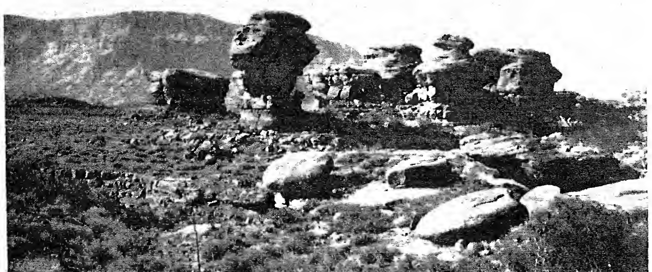


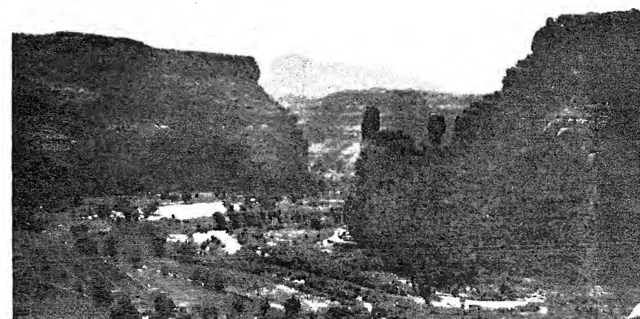
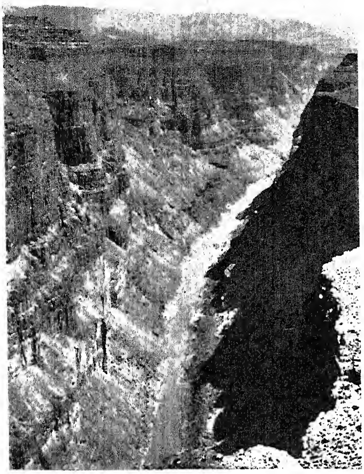


Plate 122



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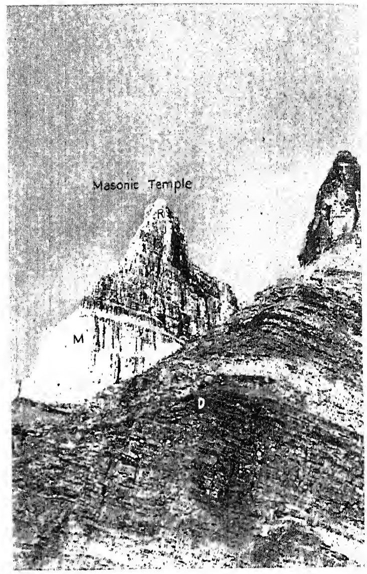

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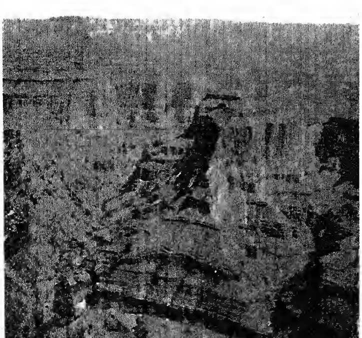


PLATE 122

Between Kanab Canyon and Tapeats Creek

A. The upper left hand photograph on the opposite page, taken by R. T. Evans while mapping this region, represents the view eastward from the canyon rim near the mouth of Kanab Creek. The Kaibab Plateau appears dimly at the sky line in the distance. The rim rock here is Redwall limestone and the rocks at river level the Tapeats sandstone.

B. Masonic Temple.

The conspicuous point of rock shown in the upper right hand corner is situated southeast of Powell Plateau and rests on a thick mass of sandstone which appears dark colored in the photograph. It is known as the Dox sandstone (D), and is one of the very old sedimentary formations. It is the upper part of the Grand Canyon series. The light-colored rock (M) at the base of the Temple is the limestone, and above this is Redwall limestone (R). The point to the right consists of Tapeats sandstone (T). In the geologists' time scale these rocks are classed as follows:

Carboniferous system
  Redwall limestone
    Unconformity
(Devonian, Silurian, and Ordovician systems not represented).
Cambrian system
  Tonto group
    Muav limestone
    Bright Angel shale
    Tapeats sandstone
      Great unconformity
Algonkian system
  Grand Canyon series
    Unkar group
      Dox sandstone

Shinumo quartzite
Hakatai shale
Bass limestone
Hotauta conglomerate
Great unconformity

Archean system
Vishnu schist

C. View up Tapeats Creek.

The photograph in the lower left hand corner was taken by Evans from the south rim of Grand Canyon looking directly into the canyon of Tapeats Creek. A small white spot at the mouth of the creek marks the position of the Colorado River. Here, as in many other places where the strata lie nearly horizontal, they form a series of steps or shelves in the sides of the canyon. On leaving the inner gorge and entering this region of stratified rocks, Major Powell thought the steps a stairway from gloom to heaven. These strata range in age from Algonkian at the river level to Redwall in the central cliff and Kaibab limestone at the top of the distant mesa.

D. Kanab Canyon.

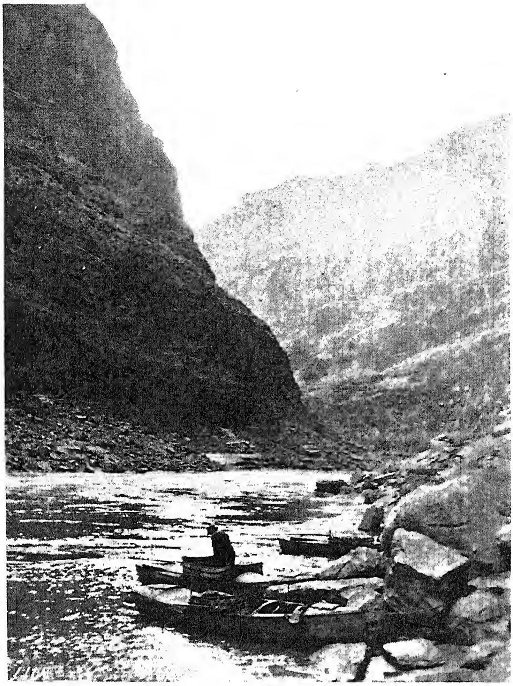
The photograph in the lower right hand corner may be recognized as the familiar illustration of Kanab Canyon. It was taken by J. K. Hillers about fifty years ago, and represents the extremely precipitous nature of the walls in this part of the canyon country.

PLATE 123A

(A) Looking down stream from just below the mouth of Kanab Canyon.

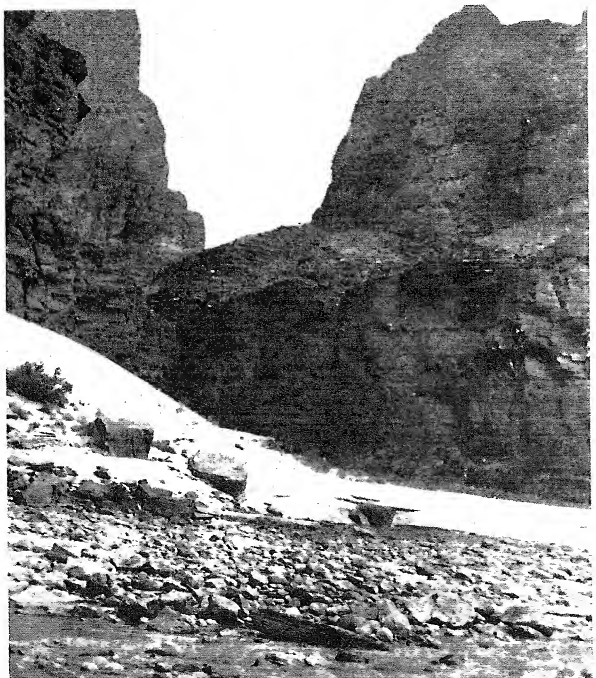
(B) Looking up stream from below Kanab Canyon. This may be identified by the notch in the rocks along the skyline at upper left of the picture.

Plate 123



A

Plate 124



A

B

PLATE 124A AND B

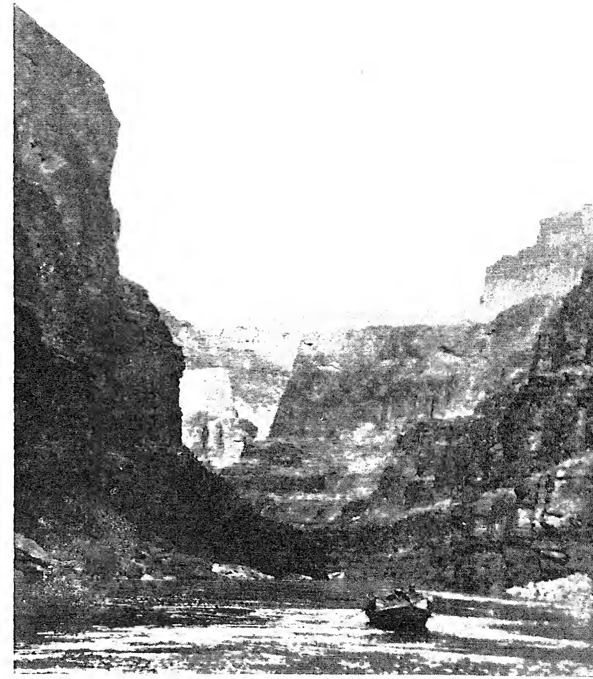
In Stephen Aisle.

PLATE 125A AND B

In Conquistador Aisle.

Plate 125

A



B

PLATE 126A AND B

Below mouth of Cataract Creek.

PLATE 127A AND B

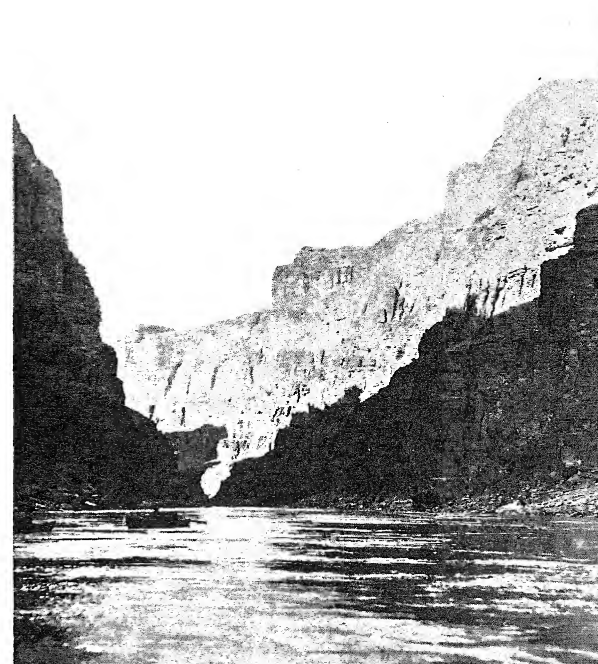
HOW WAS THE CANYON FORMED?

Scenes below Cataract Canyon near Rapid No. 114.

Many have wondered at the temerity of the adventurers in entering a place like this where escape would be difficult if possible at all, without knowing what rapids and falls were to be encountered. But the early explorers had observed that the water of the Colorado River is always muddy and, being geologists, they knew that falls cannot persist in a muddy river. Falls which may have existed at one time were long ago worn down by the myriads of sand grains which passed over their brink. Rapids are to be expected in a river which may be temporarily choked by boulders falling from the walls. But falls may not endure where much rock debris is carried. The obliteration of a fall such as that at Niagara would be a mere incident in the digging of the Grand Canyon. An infinitely greater task was accomplished by the river in removing a dam of lava which once obstructed its flow at this point.

Plate 127

A



B

PLATE 128

A

B

PLATE 128A AND B

NEAR TOROWEAP VALLEY

(A) Lava Falls.
(B) Below Lava Falls.

PLATE 129A

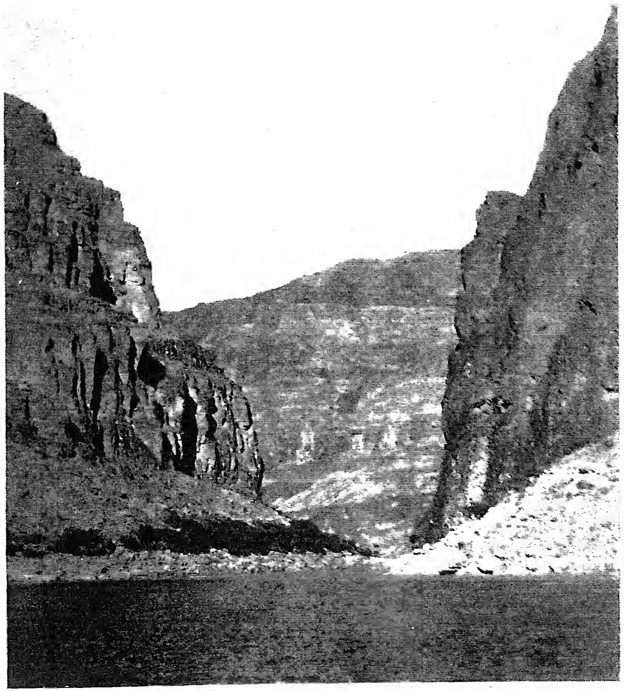
Three miles or so below Lava Falls.

PLATE 129B

Melted Rock and Melted Ice

For many miles in the lower reaches of the Grand Canyon igneous rock is found in the canyon walls. In some places remnants of the lava stand in the river, in others they are found clinging to the walls, resting on benches, or filling recesses and side gorges. The lava came in part, if not wholly, from volcanic vents where cinder cones are now situated on the north side near the brink. The molten rock extruded from these vents poured over the rim into the canyon, filling it to a depth of possibly fifteen hundred feet. A remnant of one of the lava streams appears in the photograph opposite as the dark rock in the middle of the view. For a long distance the whole north side of the canyon is lined with black basalt. At the point of eruption the rocks are faulted and those west of the fault have been depressed about eight hundred feet. The cone near the brink stands over the fissure. On the opposite side of the canyon, springs of warm, salty water issue from this fissure and deposit carbonate of lime. It has often been assumed that in order to dam a river like the Colorado, the melted basalt must have poured into the canyon very rapidly. Powell remarks on the seething commotion caused by "a river of molten rock running into a river of melted snow." If we think in terms of geologic time, doubtless the period of eruption would seem short. However, in terms of years the flood may have occurred intermittently through centuries of time.

PLATE 129



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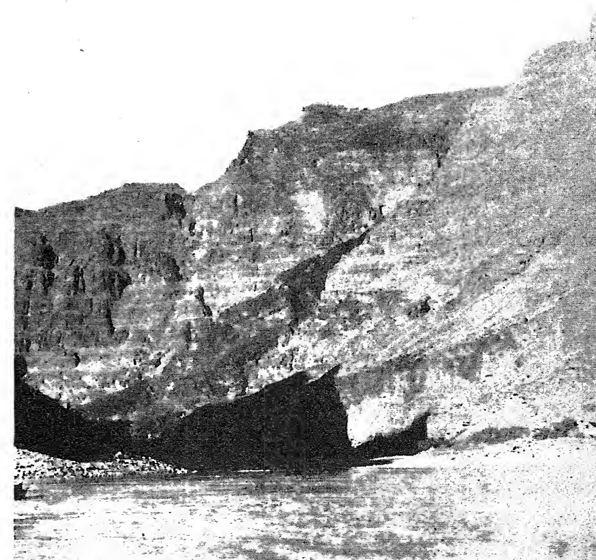
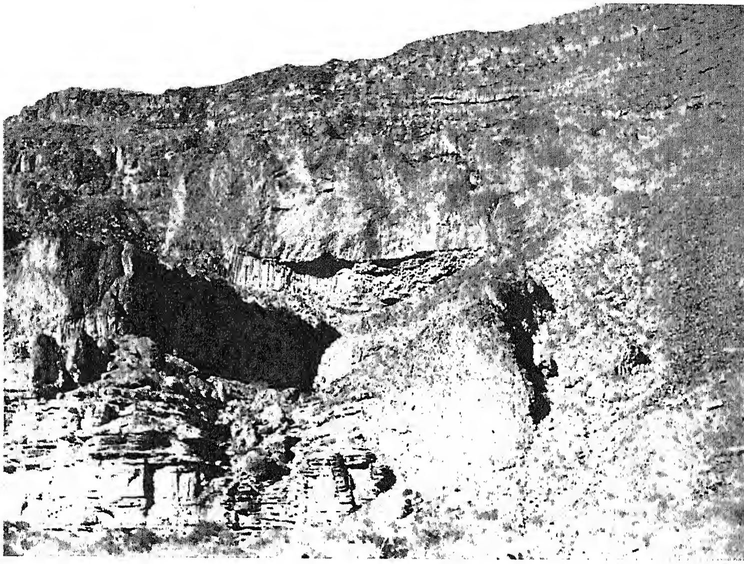


B

PLATE 130



A

B

PLATE 130A AND B

SILLS AND SEDIMENTS

(A) Lava intrusion in the north wall of the inner gorge where a small volcanic pipe broke through.

(B) Characteristic terraces in the canyon walls formed by erosion. The risers represent the broken edges of hard strata and the treads the softer layers of rock separating the hard layers. At the left in the lower photograph opposite appears a mass of lava resting on granite. This lava was poured in a molten state into the canyon where it hardened and later was partly eroded away.

PLATE 131A AND B

CANYON WALLS NEAR MT. EMMA

(A) A wall of lava where erosion following the extrusion of the molten rock has not yet entirely re-excavated the pre-existing canyon.

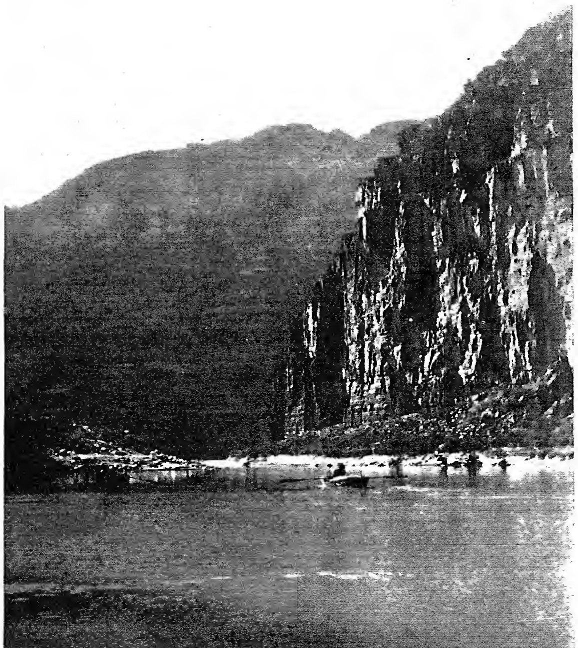
(B) Terraced canyon wall completely cleared of any lava which may once have covered it.

PLATE 131

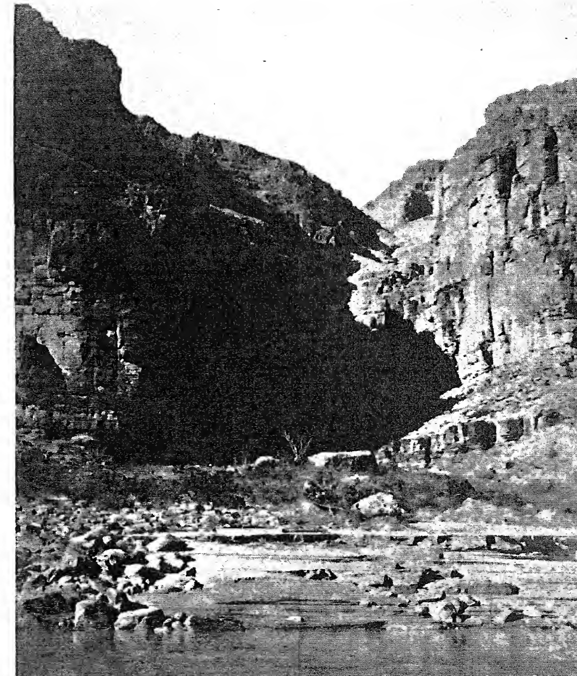
A

B

Plate 132



A



B

PLATE 132A AND B

NORTH OF DIAMOND CREEK

(A) Typical canyon walls in the lower part of Grand Canyon.

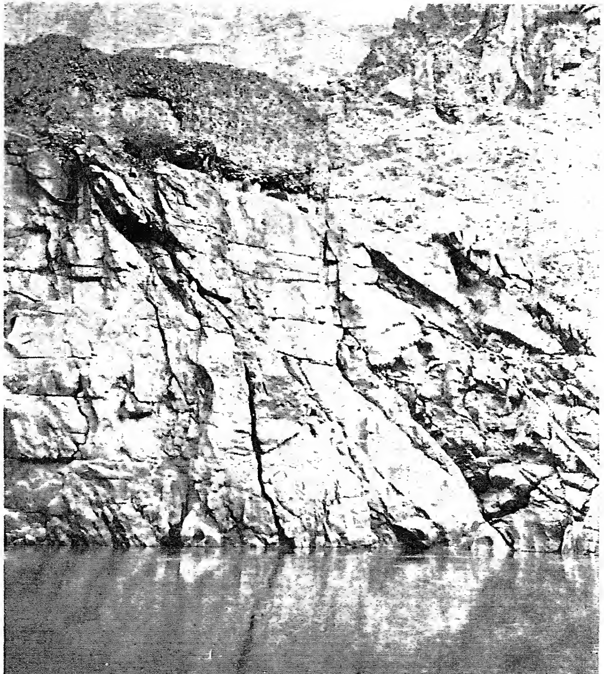
(B) Mouth of a side gorge above Rapid No. 136. The boulders in the foreground were washed down this gorge into the river. These help to retard the flow and partially to dam the river, causing rapids.

PLATE 133A AND B

(A) A shelf composed of granite capped with lava.

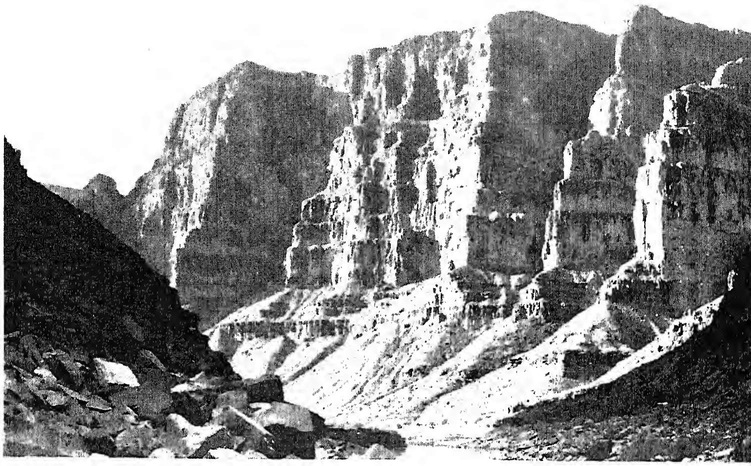
(B) A basin of travertine, where a warm spring is situated at the level of the river. The warm water carries calcium carbonate in solution. On reaching the air it cools and deposits this material, forming a mass known as travertine.

PLATE 133



A

B



A

B

PLATE 134A

A Characteristic Scene in the Lower Canyon

Canyon walls such as those shown in the upper photograph on the opposite page, made up entirely of evenly stratified rocks, are characteristic of the lower part of the Grand Canyon, where the granite and some or all of the Algonkian sedimentaries sink beneath river level. Such walls contrast sharply with those consisting partly of crystalline rocks. To one who has no personal knowledge of it, it is quite impossible to convey an adequate impression of a scene like this. One may say that the stream which is barely visible in the foreground is the great Colorado; that the blocks of rock at the left which seem so ordinary are prodigious in size; that the talus slope at the foot of the great buttressed wall is hundreds of feet high. But after all has been said, the scene has not been described. Everything in it is on a scale to which the mind is unaccustomed. Yet the photograph helps one to gain at least an impression of the glory of the landscape.

PLATE 134B

A Lava Covered Bench

There occurred in recent geologic time a lava flow that filled the inner gorge of the canyon to a height of one thousand feet or more. Some have estimated it at fifteen hundred feet. The cliffs on both sides of the canyon are smeared as though treacle had been poured over them. The volcanic field from which it came is situated north of the river and its fiery contribution poured over the brink of the outer gorge, crossed the intervening esplanade and down the walls into the inner gorge. A number of throats opened directly out into the canyon, while some broke through the wall of the inner gorge. Remnants of the flow are found in the canyon walls for many miles, some resting on benches like ornaments on a shelf, some lying on mesas like a dark covering

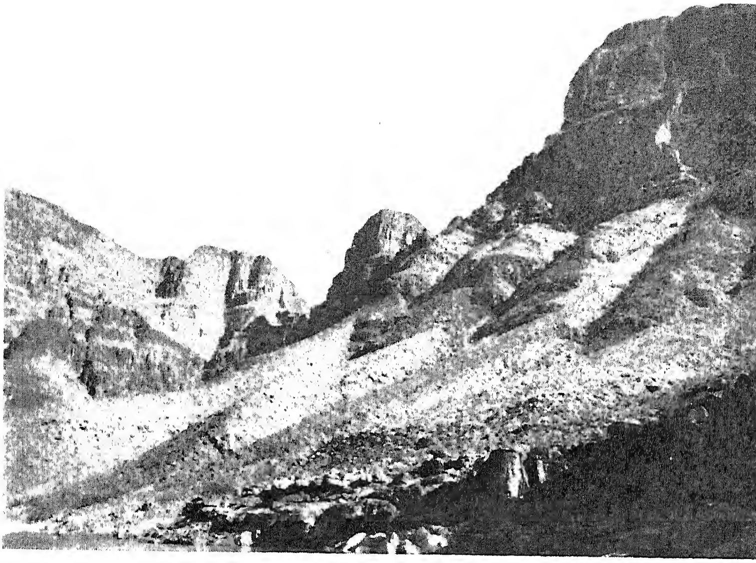
on a table. As the molten rock poured into the canyon it filled the side gorges, alcoves, and crevices, where it hardened. Most of the flood of lava has been swept away by the all-conquering river. But many remnants, such as that at the bottom of Plate 134, remain in sheltered places. Just before the river turns for its great detour to the south it crosses Toroweap Fault, whose fissure was the channel for the floods of lava forced up from below. Many volcanic cones are situated on the fault line or near it, one standing on the very brink of the canyon.

PLATE 135

(A) Canyon wall near Rapid No. 151.
(B) The grist.

The millstones that grind are themselves ground away. The grist of boulders fed into the hopper of the canyon by rocks falling from the sides of the gorge, or washed down side gulches, are slowly ground to powder, but they in turn grind the rocks of the channel, deepening the gorge and undercutting its walls. The blocks of rock are moved by the current and in colliding, each knocks bits of rocks from its neighbor and in turn is itself abraded. When reduced to a size small enough for transportation by the current, the boulders roll along the bottom and grind the bed rock. The boulder-laden stream is like a gigantic strip of sandpaper perpetually wearing away the rocks in its course, bit by bit, grinding with never-ceasing energy, never turned aside by obstacles, never discouraged by the enormity of the task. In its persistent energy the river typifies the faith that removes mountains and casts them into the sea.

PLATE 135



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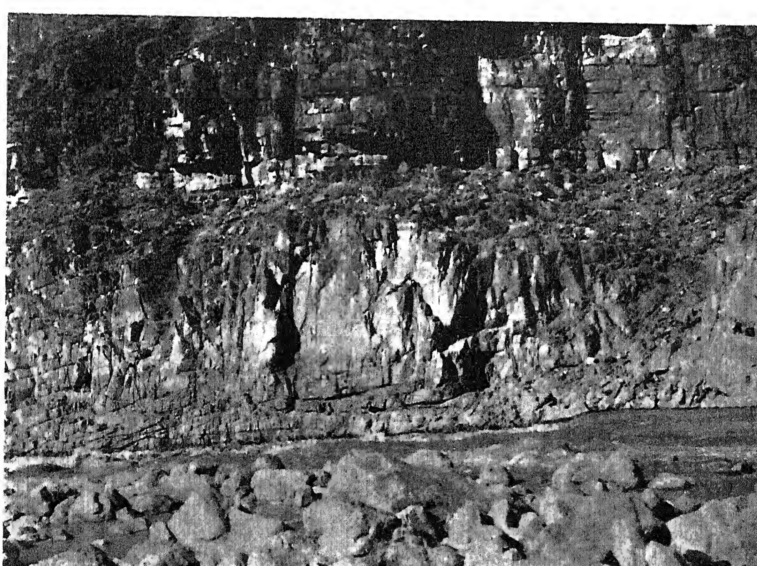


B

Plate 136

A

B

PLATE 136A AND B

Scenes above and below the mouth of Diamond Creek.

PLATE 137A

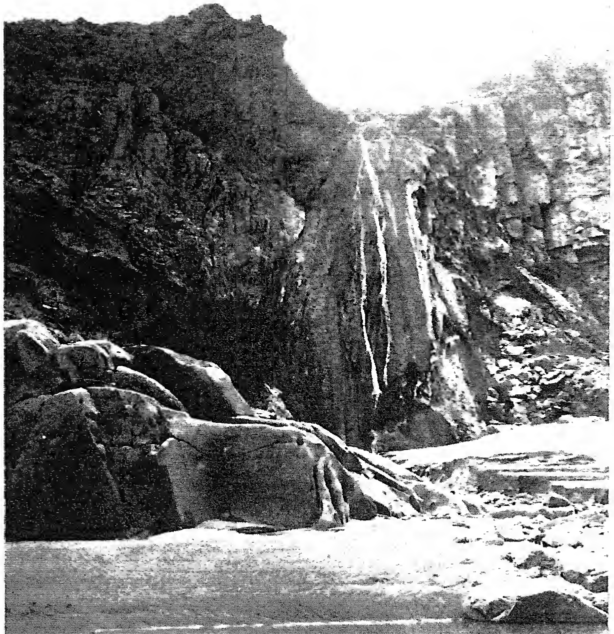
A Curtain of Travertine

In many places in the lower canyon where limestone is abundant the water issuing from crevices and caves and at ordinary springs is charged with calcium carbonate in solution. This is deposited when the water reaches the surface. Deposits of this material, called travertine, assume a great variety of forms, one of which is shown at the left on the opposite page. There are pendants somewhat resembling the stalactites of caves; curtains gracefully draped on the walls; benches built out in various forms; troughs similar to those of the well-known Mammoth Hot Springs of Yellowstone Park; grottoes decorated with delicate plants which thrive in the protected inclosure kept warm and moist like a hothouse by the regular supply of warm water.

PLATE 137B

Characteristic scene below Diamond Creek.

PLATE 137

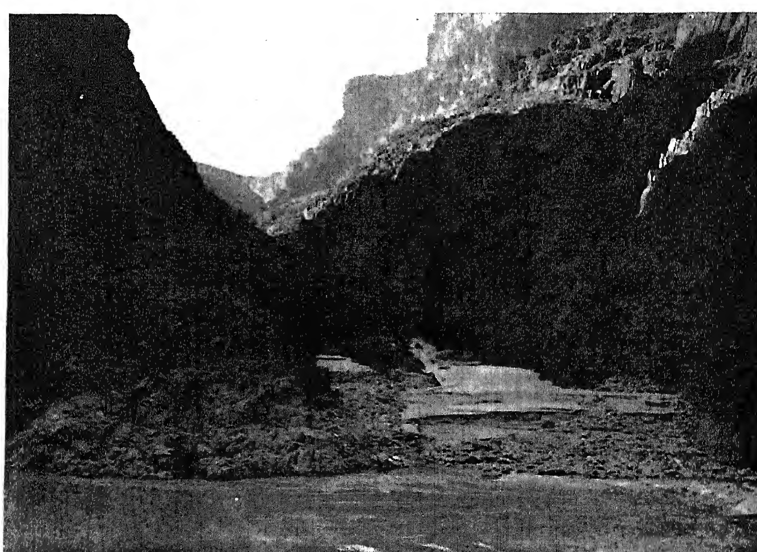


A

B

PLATE 138

A



B

PLATE 138A AND B

SOUTH BEND OF GRAND CANYON

(A) Above Separation Rapid.

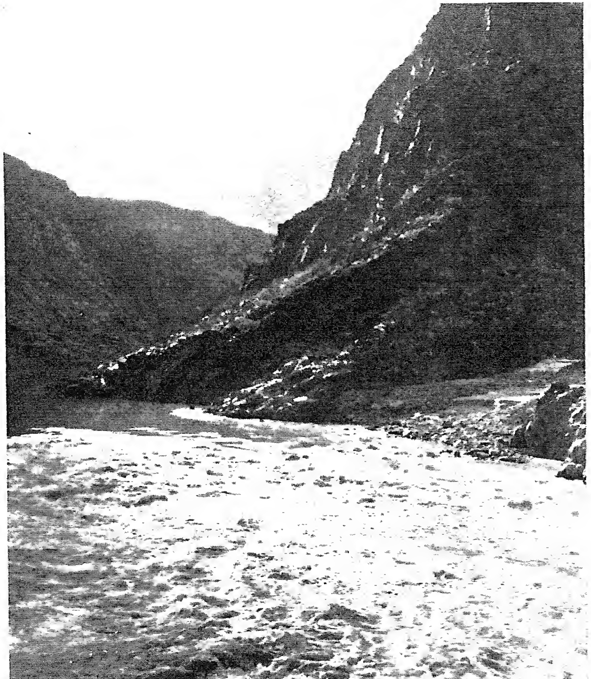
(B) Mouth of creek coming in from the left, where Major Powell's party camped August 27, 1869, and where O. G. Howland, Seneca Howland, and Wm. H. Dunn were left. They afterward climbed out on the opposite (north) side, where they were killed by the Indians.

PLATE 139

(A) Head of Separation Rapid.

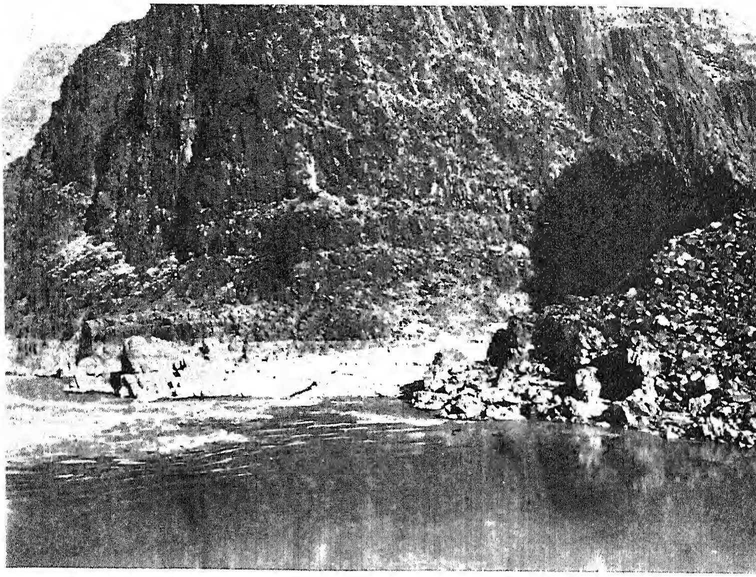
(B) Looking down stream from rocks on north side above the rapid.

PLATE 139



A

B



A

B

PLATE 140A AND B

(A) Mouth of creek entering the Colorado from the north, opposite the canyon shown in Plate 138 B. Following this side canyon to its source, the three men who were left here by Major Powell's party succeeded in climbing to the north rim.

(B) Looking down stream below Separation Rapid.

PLATE 141A AND B

SCENES IN THE SOUTH BEND OF GRAND CANYON

A. Spencer Canyon. The Colorado makes a long detour to the south around Shewits Plateau, then turns again toward the northwest before emerging from the high plateaus at Grand Wash. The photograph opposite shows the mouth of Spencer Canyon. The contribution of rocks brought in by this stream during flood time causes a very turbulent as well as dangerous rapid, the last bad rapid in the Grand Canyon.

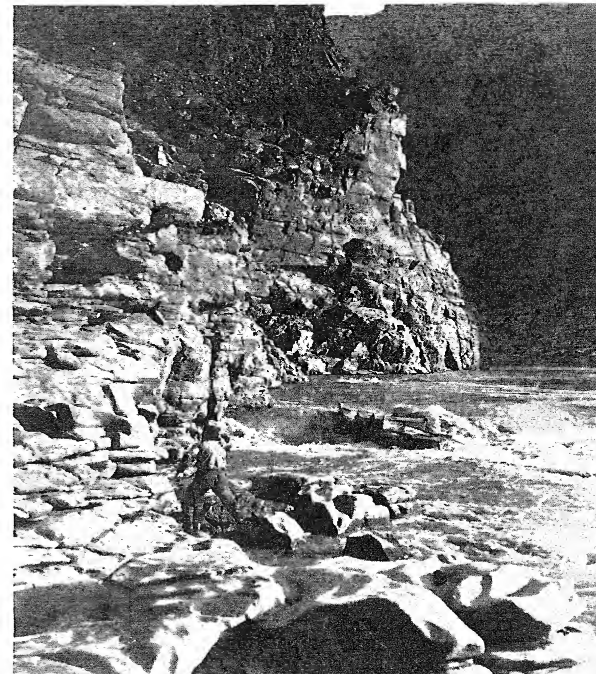
In some respects this lower part of the canyon is more impressive than any other part, although it lacks the variety of form which makes attractive the scenes near Bright Angel. It is here a single deep, narrow slash in the face of the earth. But, unfortunately, relatively little is known about it. The plateaus are high, bleak, and thinly inhabited. Approach to the canyon from above is difficult. The few who have traversed the canyon by boat have said little about the lower part, because the rough going demanded their constant attention, and, being near the end of the journey, the mind, surfeited by the never-ending succession of wonders, becomes almost languid and drowsy in the presence of scenes which at the beginning of the journey would have inspired enthusiastic interest.

B. "Lining" a boat over the take-off of the rapid just below the mouth of Spencer Canyon. Men holding the bow line are behind a shoulder of rock, while the one holding the stern line is ready to pull the boat into an eddy when the others release the bow line.

This rapid is not only swift but full of rocks. We might have run it at a higher stage of water, but even then it would have been difficult if not dangerous.

Plate 141

A



B

PLATE 142

A

B

PLATE 142A AND B

(A) At the end of the lower granite gorge.

(B) Here we made our last camp in the Grand Canyon. Snow of the high plateau shows on the upper benches.

PLATE 143A AND B

Scenes near the mouth of Grand Canyon looking back at the face of the Grand Wash escarpment.

PLATE 143

A

B

PLATE 144

A

B

PLATE 144A AND B

(A) Face of Grand Wash Cliff north of the canyon.

(B) A re-entrant, or so-called box canyon, into the limestone of the canyon wall, showing the mouth of a cave at its head.

PLATE 145

Mouth of Grand Canyon

A. A travertine curtain.

Near the mouth of Grand Canyon much travertine has been deposited on the walls. Water slowly working its way through the limestone dissolves some of the carbonate of calcium. When it reaches the air in the canyon some of the dissolved material is deposited on the walls. On a steep face of rock, as shown at the left on the opposite page, travertine drapery is formed in great variety and beauty. In some places the water dripping from an overhanging ledge has formed pendants resembling the stalactites of caves. In some places these have formed grottoes in whose moist, sheltered recesses a variety of ferns and flowering plants grow luxuriantly.

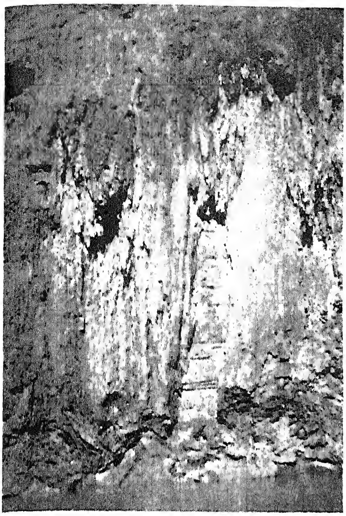
B. A travertine basin.

Where the spring water bearing lime in solution emerges near the level of the river, basins of travertine are formed. The one shown at the right has grown by building at the outer edge, even against the force of the river, thus forming a pool of clear water which contrasts sharply with the muddy water of the river.

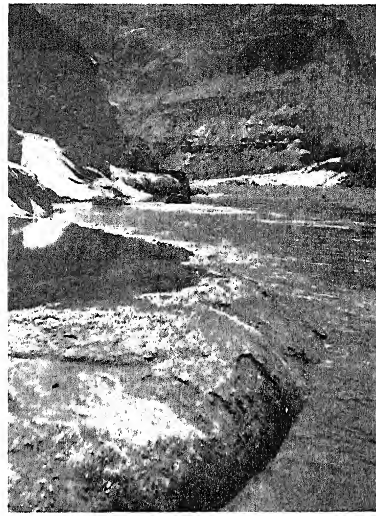
C. Mouth of the canyon from a point west of Grand Wash Fault.

At the point shown in the lower photograph on the opposite side the high plateau suddenly ends and the Colorado emerges from the narrow confines of Grand Canyon. This abrupt change is caused by displacement of the rocks at Grand Wash Fault, where a great crack formed in the crust of the earth and the rocks east of it were pushed up several thousands of feet, while those west of it were lowered and tilted. Grand Wash Fault is one of the great faults for which the canyon country is famous. The edge of the uplifted block forms a westward-facing wall of rock which towers majestically above the lower country to the west for many miles. The tilted crust block west of the fault

Plate 145



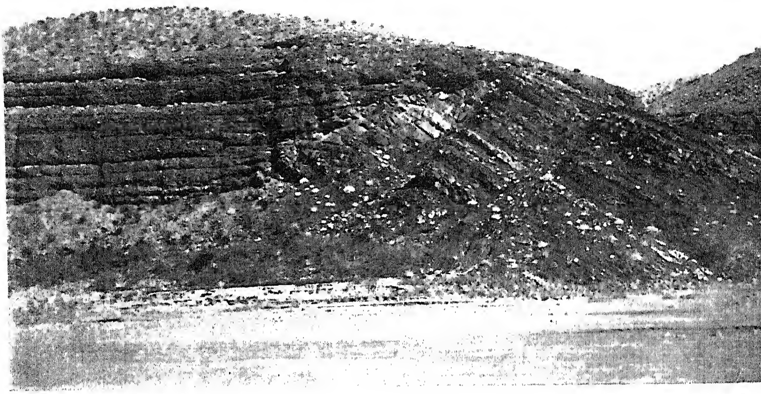
A



B

C

PLATE 146



A

B

line is many miles wide. Its surface inclines eastward toward Grand Wash Cliffs, where it is depressed, forming a great trough. The western edge of the great block is raised to form the Virgin Mountains. The depression between these mountains and the western edge of the plateau known as Grand Wash Trough is partly filled with gravel boulders and flows of lava.

PLATE 146A AND B

Gravel Beds in Grand Wash Trough

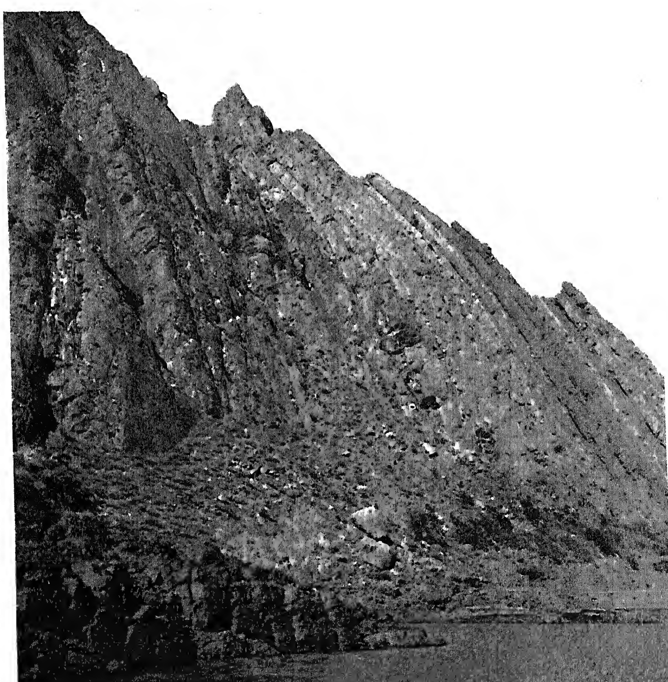
The gravel beds filling the ancient trough rest on an uneven surface of upturned and eroded sedimentary rocks. In the upper photograph they are shown built against and covering a hill of sedimentary rocks. In the lower photograph they are built against the upturned sedimentaries.

PLATE 147A AND B

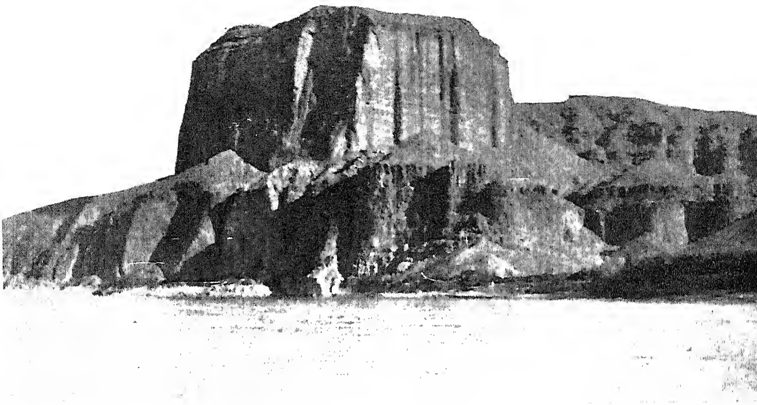
(A) Mouth of Grand Wash.

(B) Tilted sedimented rocks in the east slope of the Virgin Mountains.

A



B



A

B

PLATE 148A AND B

(A) Butte of Temple Bar conglomerate east of the mouth of the Virgin River.

(B) Entrance to Boulder Canyon. (Photo by Ransome.)

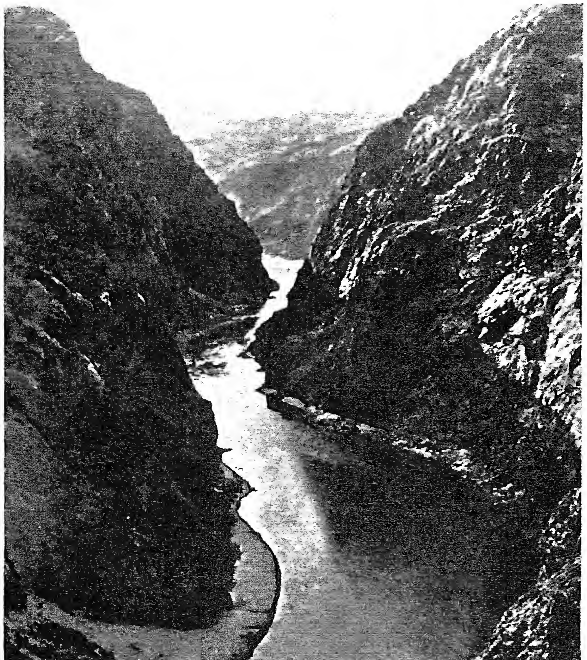
PLATE 149

BOULDER CANYON

(A) Looking down stream from a high point on the Nevada side. (Courtesy of U.S.R.S.)

(B) Lower down in Boulder Canyon.

PLATE 149

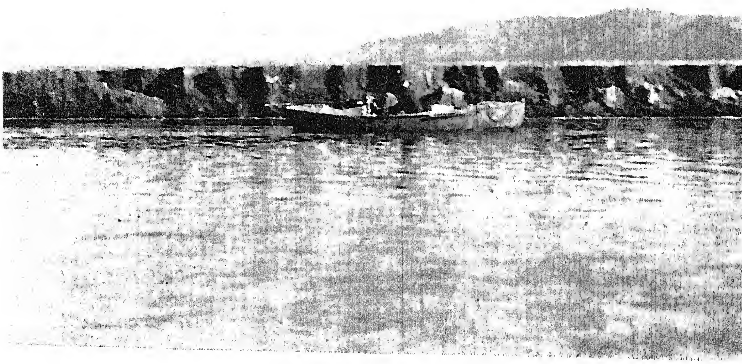


A

B

Plate 150

A



B

PLATE 150

(A) Black Canyon.

(B) A disappearing river bank.

Here is a flood plain of sand, doubtless deposited recently. Its crumbling face rises about ten feet above the surface of the river.

The carrying power of running water varies practically as the sixth power of its velocity. Therefore if the velocity decreases, its transporting capacity is enormously reduced; as for instance if its rate of flow is lessened to one-half, its power to transport is reduced to *one sixty-fourth*. (Conversely, if its velocity is doubled, its power is increased sixty-four times.) Thus it is easily seen why a stream sorts out its burden according to size as well as specific gravity, either picking it up or depositing it from time to time on its journey to the sea, but always in conformity with its rate of flow. It is also of interest that the zone of greatest velocity is not at the top but at one-third of the distance from its surface to its bed. Therefore, it always *undercuts* its banks which then, for lack of support, fall into the water as shown in the photograph.

The river was rising rapidly. Consequently, its velocity was increasing, as also was its capacity to transport. Therefore it was picking up the deficiency from this flood plain, which, being on the outside of a bend, was exposed to the greatest velocity of the water. We estimated the face of this wall was receding at the rate of one foot in five minutes.

Here Galloway nearly lost his life by permitting his boat to be swept so near the caving edge that a large mass of falling sand partly filled his boat. Had he been a couple of feet closer he would have been engulfed, and it is very doubtful if he could have saved himself.

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